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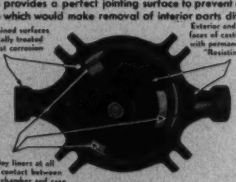
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VIABILITY OF BACTERIA IN THE PRESENCE OF PHOSPHATES

BY J. A. McCARTHY* AND W. E. CASSIDY†

[*Read November 18, 1943.*]

I. VIABILITY OF BACTERIA IN RAW-WATER SOLUTIONS OF SODIUM HEXAMETAPHOSPHATE

Within a period of about six months, the water supplies of two Massachusetts municipalities, both of which were being treated with a proprietary mixture containing primarily sodium hexametaphosphate, showed unsually high bacterial counts. Municipality A was supplied with ground water and Municipality B with surface water. In both places hexametaphosphate solutions were mixed in barrels. Municipality A made up approximately a 12% solution in a wooden barrel, bled the solution into a second barrel for dilution purposes, and fed it thence into the mains. It took approximately one week to drain the barrel containing the strong solution. Municipality B did not use so strong a solution and prepared it fresh every day. However, the mixing barrel was not completely emptied before being refilled. In both places, there was adequate incubation time for the growth of bacteria and opportunity for seeding each new batch of hexametaphosphate stock solution with previous growths.

Results of a bacteriological survey are presented in Tables 1 and 2. It will be noted that at both A and B the hexametaphosphate stock solution had a higher bacterial count as well as a higher coliform index than did the raw water from which the stock solution was made; also that hexametaphosphate dissolved in sterile water and prepared from the same lot of the compound that was used in Municipality A at the time of the trouble showed no coliform organ-

*Chief of Laboratory and †Senior Sanitary Engineering Aid, Lawrence Experiment Station, Division of Sanitary Engineering, Massachusetts Department of Public Health.

TABLE 1.—BACTERIA IN SAMPLES FROM MUNICIPALITY A—GROUND WATER SUPPLY

SAMPLE FROM	Bacteria per ml. 4 Days 20° C.	24 hours—37° C. Total	Red	Coliform Index*
Tap in pumping station — untreated water	20	2	0	0
Hexametaphosphate crystals (10 grams of hexametaphosphate to 100 grams of sterile water)	10	0	0	0
Strong hexametaphosphate stock solution	1,500,000	120,000	200	10,000
Hexametaphosphate solution as fed	1,100,000	150,000	100	100
Tap in pumping station — hexametaphosphate-treated water	70	25	1	6

*Number per 100 ml.

TABLE 2.—BACTERIA IN SAMPLES FROM MUNICIPALITY B—SURFACE WATER SUPPLY

SAMPLE FROM	Bacteria per ml. 4 Days 20° C.	24 hours—37° C. Total	Red	Coliform Index*
Pumping station at north reservoir	150	80	30	100
Surface of north reservoir at gate house	320	5	0	8
North reservoir, north pumping station, hexametaphosphate solution	1,100,000	7,000	400	100,000
Surface at south reservoir at gate house	80	16	0	6
South reservoir, south pumping station, hexametaphosphate solution	480,000	75,000	0	100
Tap on system	750	360	260	10,000
Tap on system	100	80	80	100

*Number per 100 ml.

isms and few bacteria. The addition of a large amount of chlorine to the hexametaphosphate stock solutions remedied this condition.

All of this seemed to indicate that hexametaphosphate solutions had a stimulating effect on the growth of bacteria or that the condition under which the hexametaphosphate solution was kept allowed rapid multiplication of the bacteria.* Tests have indicated that, if

*EDITOR'S NOTE: The possibility of higher counts resulting from a dispersion of clumped bacteria should not be overlooked.

properly handled, hexametaphosphate flakes do not themselves introduce bacteria into such solutions.

Viability of Organisms Normal to Water. In order to find whether the hexametaphosphate solution had any stimulating effect on bacteria when stored at room temperatures, raw water from Municipality A was placed in sterile bottles containing sufficient hexametaphosphate to make 2, 5, and 10% solutions. Five bottles of each dilution were used and allowed to stand at summer room temperatures. After 1, 7, and 24 hours, portions of the samples were removed, plated on lactose agar and inoculated into lactose broth tubes, and incubated at 37° C. Results are given in Table 3.

TABLE 3.—STIMULATION OF BACTERIAL GROWTH BY HEXAMETAPHOSPHATE

HMP*	Time of Incubation					
	1 Hour		7 Hours		24 Hours	
Percentage	Bacteria per ml.	Coliforms per 100 ml.	Bacteria per ml.	Coliforms per 100 ml.	Bacteria per ml.	Coliforms per 100 ml.
2	3	60	10	460	10,600	10,000
5	4	80	5	440	720	8,200
10	3	60	6	280	27	640

*Average number of bacteria at start = 21 per ml.
Average number of coliform organisms = 400 per 100 ml.
HMP = Hexametaphosphate.

It will be noted that there was a progressive increase in the total count and in the number of coliform organisms per 100 ml. as the length of incubation time increased. Increases in the concentration of hexametaphosphate, however, resulted in relatively smaller increases in the total count and coliform organisms. This increase seemed to indicate that the hexametaphosphate either supplied a stimulant for growth, a food substance, or a source of energy. In any event it was deemed worthy of further study.

Water from various sources was used in order to find whether stimulation was confined to specific waters or whether it was general for the waters in the vicinity of Lawrence, Mass. Three waters were chosen for study. Two were raw surface waters used in surrounding municipalities as a source of drinking water. The third was Merrimack River water that had been stored for a month and passed through an experimental sand filter.

In each study, 21 sterile bottles were used, in groups of three to which water containing the following concentrations of hexametaphosphate was added: 0 ppm. (control), 1 ppm., 10 ppm., 100 ppm., 1000 ppm., 10,000 ppm. (1.0%), 100,000 ppm. (10%). It was felt that this logarithmic progression would reasonably cover all concentrations that might be used in the treatment of water. The bottles were incubated in a water bath at temperatures between 25 and 26° C. for a period of seven days. After 1, 2, 4, and 7 days of incubation, portions of the solutions were plated on lactose agar and inoculated into lactose broth tubes. The plates were incubated for 48 hours at 37° C. before counting. The lactose tubes were examined after 24 and 48 hours of incubation at 37° C. All lactose broth tubes that showed the presence of gas were confirmed on E.M.B. agar. Only confirmed positive results were used in the tabulation of findings (Tables 4 to 6).

Tables 4, 5, and 6 show that in the lower dilutions of hexametaphosphate there was some increase over the control both in numbers of bacteria and numbers of coliform organisms. The total numbers of bacteria and especially of coliform organisms showed a tendency to decrease by the end of seven days of incubation in concentrations of hexametaphosphate below 1000 ppm. In all three waters after 1-day incubation, there was a sharp drop at 1000 ppm. of HMP in the numbers of bacteria as compared with lower concentrations. However, as the incubation time increased, the total numbers of bacteria rose until at some concentration of HMP, at or above 1000 ppm., there was a higher number of bacteria than in any other concentration at any time. The relative numbers of coliform organisms also increased at concentrations of 1000 ppm. of HMP or above. In the filtered water, the maximum stimulation was at 1000 ppm. of HMP; in the lake water, the highest stimulation was at 100,000 ppm. of HMP after seven days of incubation; and in the pond water, the highest stimulation was at 10,000 ppm. of HMP at 4 days of incubation, and 100,000 ppm. of HMP at 7 days of incubation.

In order to determine whether the stimulating action was specific for one or more types of coliform organisms, colonies were picked from the E.M.B. plates used in confirmation of presumptive tubes from the test reported in Table 6. Colonies were picked only from plates which were streaked from dilutions higher than any dilution

TABLE 4.—GROWTH OF BACTERIA IN HEXAMETAPHOSPHATE-TREATED FILTERED WATER

HMP* in ppm.	Length of Incubation: 1 Day Bacteria per 100 ml.	1 Day Coliforms per 100 ml.	2 Days Bacteria per 100 ml.	2 Days Coliforms per 100 ml.	4 Days Bacteria per 100 ml.	4 Days Coliforms per 100 ml.	7 Days Bacteria per 100 ml.	7 Days Coliforms per 100 ml.
0	11,000	0.7	261,000	0.7	27,300	0.7	8,100	0.0
1	106,000	0.0	543,000	1.3	24,300	1.3	8,100	0.0
10	117,000	1.3	1,350,000	2.0	44,000	1.3	33,500	0.0
100	1,600,000	4.0	2,000,000	3.3	110,000	3.3	44,000	0.0
1,000	100	4.6	301,000	335	320,000	3340	3,400,000	3700
10,000	900	0.0	2,900	0.0	440,000	1.3	900,000	0.7
100,000	0.0	0.0	1,300	0.0	12,000	0.0	1,520,000	0.0

*Average number of bacteria at start = 1400 per 100 ml.
Average number of coliform organisms at start = 0 per 100 ml.
HMP = Hexametaphosphate.

TABLE 5.—GROWTH OF BACTERIA IN HEXAMETAPHOSPHATE-TREATED RAW POND WATER

HMP* in ppm.	Length of Incubation: 1 Day Bacteria per 100 ml.	1 Day Coliforms per 100 ml.	2 Days Bacteria per 100 ml.	2 Days Coliforms per 100 ml.	4 Days Bacteria per 100 ml.	4 Days Coliforms per 100 ml.	7 Days Bacteria per 100 ml.	7 Days Coliforms per 100 ml.
0	69,000	0.0	5,100,000	0.0	4,800,000	0.0	4,500,000	0.0
1	730,000	3.3	6,100,000	1.3	3,700,000	0.0	3,000,000	1.3
10	210,000	2.0	5,300,000	3.3	8,400,000	2.6	1,200,000	0.7
100	130,000	1.3	5,400,000	0.7	7,000,000	0.0	260,000	0.0
1,000	1,900	0.7	2,760,000	0.7	13,100,000	1.3	5,300,000	0.7
10,000	31,500	2.6	28,900,000	39	64,000,000	3300	12,500,000	336
100,000	1,000	0.0	7,800	0.7	700,000	335	35,000,000	333,000

*Average number of bacteria at start = 1400 per 100 ml.
Average number of coliform organisms at start = 0 per 100 ml.
HMP = Hexametaphosphate.

TABLE 6.—GROWTH OF BACTERIA IN HEXAMETAPHOSPHATE-TREATED RAW LAKE WATER

HMP* in ppm.	Length of Incubation							
	1 Day		2 Days		4 Days		7 Days	
	Bacteria per 100 ml.	Coliforms per 100 ml.	Bacteria per 100 ml.	Coliforms per 100 ml.	Bacteria per 100 ml.	Coliforms per 100 ml.	Bacteria per 100 ml.	Coliforms per 100 ml.
0	2,900,000	7.3	673,000	5.3	75,000	2	25,000	1.3
1	2,800,000	10	230,000	6	63,000	2.7	30,000	0.0
10	2,900,000	10	2,450,000	10	499,000	2	116,000	1.3
100	2,500,000	370	6,400,000	70	490,000	40	220,000	8
1,000	44,000	40	2,700,000	3700	540,000	34,000	240,000	33,700
10,000	30,300	70	2,500,000	7000	126,000,000	37,000	370,000,000	37,000
100,000	500	4	900	100	44,000,000	700,000	690,000,000	7,000,000

*Average number of bacteria at start = 14,000 per 100 ml.
Average number of coliform organisms at start = 10 per 100 ml.
HMP = Hexametaphosphate.

of the raw lake water that gave positive results. If more than one type of coliform colony appeared, all types were picked. Results are given in Table 7. In all, 33 cultures were differentiated by their

TABLE 7.—DIFFERENTIATION OF CULTURES FROM LAKE WATER TREATED WITH HEXAMETAPHOSPHATE

Number	Indol	Methyl Red	Voges Proskauer	Citrate	Type
21	+	+	—	—	*E. coli*
5	—	+	—	—	*E. coli*
1	+	—	+	+	*A. aerogenes*
2	—	—	+	+	*A. aerogenes*
3	—	—	—	+	*A. aerogenes*
1	—	+	—	+	Intermediate

Imvic reactions. By far the highest percentage was *E. coli*, but *A. aerogenes* and intermediates were also present. Apparently all members of the coliform group are stimulated.

In order to be absolutely certain that there was a large increase in the number of coliform organisms held in hexametaphosphate solutions, a pure-culture test was carried out. Water taken from the Merrimack River was selected since it was an easily available supply and was known to be relatively free of toxic industrial wastes. This water was filtered through a Seitz filter as was a 10% hexametaphosphate solution. Logarithmic dilutions of the hexametaphosphate from 1 to 10,000 ppm. were made and inoculated with a suspension of *E. coli* obtained from a routine sample examined at the laboratory. Three raw-water controls were also inoculated. Five 10-ml. lactose broth tubes from both the filtered 10% hexametaphosphate solution and the filtered raw water were inoculated and incubated at 37° C. for 48 hours. The results observed are given in Table 8. Here too there was a somewhat higher number of coliform organisms in the concentrations of hexametaphosphate below 1000 ppm. than in the control. However, the highest numbers were associated with concentrations above 1000 ppm. of HMP.

Viability of Pathogens. Up to this point in our studies, the work had been confined to ordinary water bacteria and the coliform group of organisms. The next step was to determine the effect of hexameta-

TABLE 8.—VIABILITY OF *E. coli* IN FILTERED RAW WATER

HMP* ppm.	Length of Incubation 1 Day *E. coli* per 100 ml.	2 Days *E. coli* per 100 ml.	4 Days *E. coli* per 100 ml.	7 Days *E. coli* per 100 ml.
0	2,400	170,000	700,000	170,000
1	2,800	130,000	500,000	120,000
10	8,800	180,000	800,000	500,000
100	63,000	150,000	1,600,000	1,300,000
1,000	13,000	300,000	200,000,000	250,000,000
10,000	130,000	75,000,000	730,000,000	800,000,000
100,000	18,000	130,000	120,000,000	150,000,000

*Averaeg number of bacteria in inoculated controls = 570 per ml.
No growth in 10-ml. tubes inoculated with the filtered water.
HMP = Hexametaphosphate.

phosphate on pathogenic bacteria. Since it was impossible to find a water containing naturally a large number of pathogens, all pathogens had to be laboratory grown and the results are, therefore, not necessarily representative of conditions that would occur in nature.

In order to determine whether *E. typhi* would grow in hexametaphosphate solutions as did *E. coli*, a similar experiment was set up, except that a recently isolated culture of *E. typhi* obtained from the Division of Communicable Diseases of the Massachusetts Department of Public Health was used for inoculation purposes. The results observed are summarized in Table 9.

TABLE 9.—VIABILITY OF *E. typhi* IN FILTERED RAW WATER

HMP* ppm.	Length of Incubation 1 Day *E. typhi* per 100 ml.	2 Days *E. typhi* per 100 ml.	4 Days *E. typhi* per 100 ml.	7 Days *E. typhi* per 100 ml.
0	39,000	12,000	3,800	3,500
1	33,000	11,000	4,500	3,000
10	60,000	41,000	17,000	7,300
100	200,000	260,000	220,000	43,000
1,000	21,000	26,000	80,000,000	160,000,000
10,000	8,700	7,500	4,100	4,000
100,000	0	0	0	0

*Average number of *E. typhi* at start = 89,000 per 100 ml.
No growth in 10-ml. controls with the filtered water.
HMP = Hexametaphosphate.

The culture in *E. typhi* used did not develop as high a total number of organisms after incubation in hexametaphosphate solutions as did the culture of *E. coli*. *E. typhi* in hexametaphosphate concentrations of 0, 1, and, to a lesser extent, 10 ppm. showed a marked decrease in the first day and a continued drop throughout the seven days. In a concentration of 100 ppm. of HMP, there was a sharp increase in the first day which continued through the second day, after which a decrease in the total number set in. For the culture of *E. typhi* in a concentration of 1000 ppm. of HMP, however, a sharp drop in the total number during the first day was followed by a slight rise during the second day and a tremendous increase by the fourth and seventh day.

E. typhi in concentrations of hexametaphosphate of 10,000 and 100,000 ppm. showed the greatest difference from *E. coli*. In the highest concentration of HMP, all typhoid organisms were killed in the first day. In 10,000 ppm. of HMP, there was a sharp decrease during the first day, followed by a more gradual decrease for the remaining six days.

In view of these results, it would appear to be important for municipalities that wish to add hexametaphosphate to their water supplies, to be fully aware of the possible growth of organisms in hexametaphosphate solutions. A high chlorine residual should be maintained at all times in any barrel or container containing solutions of hexametaphosphate. In the final concentrations used for softening water by the threshold method, the hexametaphosphate has little effect on bacteria.

Summary

1. Hexametaphosphate solutions in two municipalities, one of which used ground water, the other surface water, showed enormous increases in the total number of bacteria and in the number of coliform organisms.

2. Hexametaphosphate in various concentrations added to raw water from three sources showed enormous increases in the number of bacteria in concentrations of hexametaphosphate above 1000 ppm.

3. A pure culture of *E. coli* when added to sterile hexametaphosphate solutions of various concentrations grew very well in concentrations above 1000 ppm.

4. A culture of *E. typhi* also grew in hexametaphosphate solutions but not to the same extent as the *E. coli*.

Addendum

After this work had been completed an inter-office communication to the district offices of one company selling a commercial brand of sodium hexametaphosphate was brought to our attention. This letter advised that it would be desirable to sterilize the hexametaphosphate solutions with 10 grams of HTH or Perchloron or 50 ml. of Clorox per 50 gallons of stock solution. In order to determine the efficiency of this recommendation the following experiment was carried out:

To two groups of six sterile bottles were added 100 ml. of raw water and either 10 grams of hexametaphosphate or 1.0 gram of hexametaphosphate. The resulting concentrations of hexametaphosphate were 10,000 and 100,000 ppm. respectively. While the salt was dissolving, 1 ml. of 1/190 concentration of HTH was added to three bottles of each concentration of the hexametaphosphate and 1 ml. of 5/190 concentration of Clorox to the other 3 bottles of each concentration. A sample of the water was then inoculated into lactose broth tubes and onto lactose agar plates. The tubes were read after 24 and 48 hours of incubation at 37° C., and all positive tubes were confirmed on E.M.B. agar. The lactose plates were counted after 48 hours of incubation at 37° C. The chlorine residuals at the start were read after about a 1-hour period of contact.

After 1, 2, 4, and 7 days of incubation at 25-26° C., the chlorine residuals were read, and lactose broth tubes and lactose agar plates were inoculated. The bottles were carefully protected against airborne contamination and contained no demonstrable bacteria in the chlorine-hexametaphosphate solution at any time during the seven-day incubation period, even though the controls contained an average of 700 coliform organisms per 100 ml. and an average of 95 bacteria per ml. at the start. The chlorine residuals are given in Table 10.

It will be noted that residuals in the solutions containing Clorox were much lower than in the solutions containing HTH. It will also be noted that the residual dropped to zero in the Clorox solutions before the end of the 7-day period and to a comparatively low value in the

TABLE 10.—CHLORINE RESIDUALS IN HEXAMETAPHOSPHATE—CHLORINE SOLUTIONS

Solution	Residual Chlorine in ppm. Length of Incubation				
	Start	1 Day	2 Days	4 Days	7 Days
10% HMP* plus Clorox	1.2	0.26	0	0	0
1.0% HMP plus Clorox	2.5	1.6	.21	trace	0
10% HMP plus HTH	15.0	12.0	9.0	6.0	trace
1.0% HMP plus HTH	15.0	12.0	9.0	6.0	0.5

*HMP = Hexametaphosphate.

HTH solutions. Evidently the commercial hexametaphosphate either had a chlorine demand or a neutralizing action on small amounts of chlorine, since the residuals in the 10% solutions of HMP were less than in the 1% solutions of HMP.

In view of the variations in chlorine demands of water supplies, retention times of stock solutions, and concentrations of stock solutions, it is felt that it would be preferable to maintain chlorine residuals of at least 1.0 ppm. in the hexametaphosphate stock solutions at all times. If this procedure is followed, accidental contamination by hands, dust, or dirt will be neutralized. This might otherwise not be the case, especially if a Clorox solution of the recommended strength were used.

II. VIABILITY OF BACTERIA IN RAW-WATER SOLUTIONS OF PHOSPHATES

In the work described in Part I of this paper, it was found that sodium hexametaphosphate in concentrations of 1000 ppm. or more brought about a marked increase in the numbers of bacteria in the natural waters found in the neighborhood of Lawrence, Mass. The present section describes further experiments to determine whether or not this increase was peculiar to sodium hexametaphosphate, or to hexametaphosphate ion, or whether other phosphates would give similar results.

All the chemicals used in the work were C.P. reagents, except the hexametaphosphate which was a commercial product, not chemically pure, and containing sodium carbonate and bicarbonate and tetra sodium pyrophosphate. The amount of phosphate used in each experi-

ment was based on the chemical equivalent of a given concentration of pure sodium hexametaphosphate, because of our belief that the reactions involved were of a chemical nature, and more comparable information would be obtained if chemical equivalents were employed.

The first two experiments were set up in the same way as in the original hexametaphosphate studies. Twenty-one bottles, each containing 100 ml. of the solution of the salt being tested were incubated at 25 to 26°C. The concentrations of phosphates were the chemical equivalents of 0, 1, 10, 100, 1000 and 10,000 ppm. of sodium hexametaphosphate. As a control, a solution of 10,000 ppm. of sodium hexametaphosphate was used. Preliminary work had shown that, while bacteria would grow in 100,000 ppm. of the phosphates tested, the growth was slow. Hence it was felt that the hexametaphosphate control would be of more value for comparisons than would 100,000 ppm. of the phosphate being tested. Three bottles of each concentration were used. Results are averages of three tests.

Portions from the bottles were plated on lactose agar and inoculated into lactose broth after 1, 2, 4, and 7 days of incubation. The solutions were made with raw Merrimack River water, since this water was easily available, was relatively free of toxic industrial wastes, and had a concentration of bacteria and coliform organisms such as to allow for an easily demonstrable increase or decrease in these microorganisms. The lactose broth tubes which showed the presence of gas after 24 or 48 hours of incubation at 37°C. were streaked on E.M.B. agar, and only those tubes which showed positive confirmations on this medium are included in the tables. All lactose plates were incubated at 37°C. for 48 hours.

Sodium Orthophosphate. The mono-sodium salt was used in order to eliminate the addition of another acid radical. The concentrations of phosphate taken were chemically equivalent to sodium hexametaphosphate if this hexametaphosphate were completely broken down to orthophosphate. The solutions with the exception of that containing 10,000 ppm. of hexametaphosphate were adjusted to a pH of 6.8 with NaOH. Results are given in Table 11.

It will be noted that the most significant differences from the raw water occurred at a concentration equivalent of 10,000 ppm. of orthophosphate. The total numbers of bacteria and coliform organisms were

TABLE 11.—VIABILITY OF BACTERIA IN RAW-WATER SOLUTIONS OF SODIUM ORTHOPHOSPHATE

Phosphate Ion Equivalent to Hexametaphosphate, ppm.	Period of Incubation 1 Day Bacteria per 100 ml.	1 Day Coliform per 100 ml.	2 Days Bacteria per 100 ml.	2 Days Coliform per 100 ml.	4 Days Bacteria per 100 ml.	4 Days Coliform per 100 ml.	7 Days 100 ml. per Bacteria	7 Days 100 ml. per Coliform
0	660,000	10,000	970,000	7,000	1,500,000	700	190,000	100
1	330,000	10,000	510,000	1,000	480,000	400	160,000	70
10	370,000	10,000	260,000	1,000	520,000	300	170,000	40
100	760,000	70,000	1,400,000	34,000	250,000	3,700	150,000	370
1,000	1,400,000	7,000	63,000	4,000	1,700,000	4,000	170,000	400
10,000	146,000,000	400,000	370,000,000	1,000,000	38,000,000	700,000	15,000,000	1,000,000
HMP 10,000	910,000	70,000	38,000,000	700,000	100,000,000	400,000	250,000,000	700,000

Average number of bacteria at start = 140,000 per ml.
Average number of coliform organisms at start = 10,000 per ml.
HMP = Sodium Hexametaphosphate.

much larger even after one day's incubation at 25 to 26°C. than in the raw water or any concentration below 10,000 ppm. Furthermore, this relation remained relatively constant throughout the 7-day period. The organisms in 10,000 ppm. of hexametaphosphate solution multiplied much more slowly than in the orthophosphate solution, but they maintained an increase throughout the seven days and after 4 and 7 days of incubation exceeded the total numbers of bacteria in the orthophosphate solutions which showed a decline in total numbers after 4 and 7 days incubation.

Tetra-Sodium Pyrophosphate. Chemical equivalents of tetra-sodium pyrophosphate were used assuming that both the pyro- and hexametaphosphates were completely broken down to orthophosphate. In this case it was necessary to use an acid for adjustment since no other form of sodium pyrophosphate than the tetra-sodium pyrophosphate was available. Hydrochloric acid was selected since it was felt that this would have the least effect. The pH was adjusted to 6.8. Results are given in Table 12.

Here, too, it will be noted that in the 10,000-ppm. pyrophosphate solution the stimulation of bacterial growth was greater than in the 10,000-ppm. hexametaphosphate solution and that the pyrosalt maintained its superiority throughout the seven-day period. During this experiment, chemical determinations were made to determine the extent of the breakdown in the 10,000-ppm. hexametaphosphate solutions. It was found that only 0.45% of the hexametaphosphate broke down into orthophosphate during the 7-day period.

Since the maximum effects of the phosphates seemed to occur at equivalent concentrations around 10,000 ppm. or 1%, the following experiments were run using only the chemical equivalents of this concentration of hexametaphosphate. The use of this method allowed the testing of a larger number of salts at one time and resulted in quicker determinations as well as a better comparison of their effects on bacteria.

Sodium Salts of Phosphate. The following salts were used. All were adjusted to pH 6.7 to 6.9:

1. 0.2 gram of sodium orthophosphate, adjusted with NaOH.
2. 0.2 gram of sodium orthophosphate, adjusted with NaOH, with the addition of 0.3 gram NaCl.

TABLE 12.—VIABILITY OF BACTERIA IN RAW-WATER SOLUTIONS OF SODIUM PYROPHOSPHATE

Pyrophosphate Equivalent to Hexametaphosphate, ppm.	Period of Incubation: 1 Day Bacteria per 100 ml.	1 Day Coliform per 100 ml.	2 Days Bacteria per 100 ml.	2 Days Coliform per 100 ml.	4 Days Bacteria per 100 ml.	4 Days Coliform per 100 ml.	7 Days Bacteria per 100 ml.	7 Days Coliform per 100 ml.
0	58,000	4,000	1,600,000	1,000	1,300,000	400	1,000,000	370
1	190,000	7,000	1,300,000	7,000	720,000	400	600,000	40
10	230,000	7,000	1,200,000	1,000	1,000,000	100	1,000,000	70
100	1,100,000	10,000	4,200,000	4,000	800,000	100	730,000	70
1,000	570,000	4,000	59,000,000	7,000	30,000,000	37,000	19,000,000	3,700
10,000	5,000,000	340,000	450,000,000	100,000,000	310,000,000	40,000,000	290,000,000	70,000,000
HMP 10,000	1,300,000	400,000	100,000,000	3,700,000	31,000,000	7,000,000	160,000,000	700,000

Average number of bacteria at the start = 860,000 per 100 ml.
Average number of coliform organisms at the start = 10,000 per 100 ml.
HMP = Sodium Hexametaphosphate.

3. 1.0 gram hexametaphosphate.
4. 1.0 gram hexametaphosphate plus 0.3 gram NaCl.
5. 2.2 grams sodium pyrophosphate, adjusted with H_2SO_4.
6. 2.2 grams sodium pyrophosphate, adjusted with HCl.
7. 0.73 gram sodium pyrophosphate, adjusted with HCl.

In (1) (2) and (7) the equivalents were calculated on the basis of no reversion to orthophosphate, in (5) and (6) calculations were based on reversion. Solution (2) was to furnish chloride ion equivalent to that from HCl in the pyrophosphate solution, to see if this chloride ion had any effect on coliform growth. Solutions (5) and (6) were chosen to show the effect of different anions. The results obtained are given in Table 13.

It will be noted that the solutions containing 0.73 gram of pyrophosphate per 100 ml. had the highest total number of bacteria as well as the highest coliform index for ithe first day and remained among the highest in these respects throughout the seven days. After 24 hours of incubation at 25 to 26°C., the higher concentration of pyrophosphate contained a much lower total number of bacteria than did either the smaller amounts of pyrophosphates or the orthophosphates, but it had a higher coliform index than did the orthophosphates. After 24 hours, the pyrophosphates exceeded the orthophosphates in both total numbers and coliform index. It should be noted again that the coliform index for pyrophosphates was far higher than for any other salts tested.

The pyrophosphate adjusted with sulfuric acid showed slightly higher results throughout the seven days than did the pyrophosphate adjusted with HCl.

The addition of NaCl gave slightly higher results for both orthophosphate and hexametaphosphate, but the difference is not sufficient to explain the higher results obtained in the pyrophosphate solutions as compared with the orthophosphate or hexametaphosphates. The same relationships noted in Table 11 between hexametaphosphate and orthophosphate were again observed, *i.e.*, the numbers of bacteria in the orthophosphate were higher than in hexametaphosphate during the first two days of incubation, but they gradually decreased while those in hexametaphosphate gradually increased until they exceeded the numbers in orthophosphate.

TABLE 13.—VIABILITY OF BACTERIA IN RAW-WATER SOLUTIONS OF SODIUM SALTS OF VARIOUS PHOSPHATES

Phosphate Ion Equivalent to 1 % Hexametaphosphate	Period of Incubation							
	1 Day		2 Days		4 Days		7 Days	
	Bacteria per 100 ml.	Coliform per 100 ml.	Bacteria per 100 ml.	Coliform per 100 ml.	Bacteria per 100 ml.	Coliform per 100 ml.	Bacteria per 100 ml.	Coliform per 100 ml.
0.2 gram orthophosphate adjusted with NaOH	28,000,000	7,000	106,000,000	4,000	19,000,000	3,700	4,000,000	3,700
0.2 gram orthophosphate NaOH plus 0.3 gram NaCl.	110,000,000	100,000	170,000,000	70,000	43,000,000	40,000	14,000,000	10,000
10,000 ppm. or 1.0% HMP	470,000	70,000	47,000,000	40,000	24,000,000	40,000	15,000,000	40,000
10,000 ppm. or 1.0% HMP plus 0.3 gram NaCl.	760,000	100,000	30,000,000	100,000	55,000,000	700,000	32,000,000	700,000
2.2 grams pyrophosphate adjusted with H_2SO_4	6,300,000	700,000	260,000,000	100,000,000	310,000,000	100,000,000	330,000,000	70,000,000
2.2 gram pyrophosphate adjusted with HCl	1,500,000	370,000	230,000,000	40,000,000	280,000,000	100,000,000	260,000,000	40,000,000
0.73 gram pyrophosphate adjusted with HCl	170,000,000	4,000,000	500,000,000	40,000,000	380,000,000	40,000,000	390,000,000	70,000,000

Average number of bacteria at the start = 66,000 per 100 ml.
Average number of coliform organisms at the start = 10,000 per 100 ml.
HMP = Sodium Hexametaphosphate.
Orthophosphate = NaH_2PO_4
Pyrophosphate = $Na_4P_2O_7$

Variations in Ions. In the final experiment, an effort was made to tie up a few loose ends. The general procedure was very similar to that of the preceding experiment. Since 0.73 gram of pyrophosphate gave highest results and since adjustment with sulfuric acid led to higher results than adjustment with HCl, the first three series of bottles were a check on these results along with the addition of solutions adjusted with nitric acid. The first three bottles were adjusted with hydrochloric acid. The second three were adjusted with sulfuric acid and the third three with nitric acid.

In view of the fact that the commercial sodium hexametaphosphate contained other salts as well, a pure salt was made by heating sodium metaphosphate to a temperature of 640°C. in a muffle furnace. This salt, when cooled rapidly, formed a clear glass of low pH that had to be adjusted with sodium hydroxide.

The final nine bottles were used for a series of three orthophosphate salts. Up to this time all the work had been done with variations in anions. In this series an ammonium and a potassium salt were used with a sodium salt for comparison of cations. The results obtained are given in Table 14.

Here again the growth in pyrophosphate solutions at the start was better than in any other solutions tested. However, while the numbers of bacteria in pure sodium hexametaphosphate never exceeded the total numbers of bacteria found in pyrophosphate, the coliform index on the seventh day slightly exceeded the highest coliform index of pyrophosphate. The total numbers of bacteria in hexametaphosphate was again much slower in rising than in pyrophosphates or orthophosphate. The total numbers of bacteria and coliform organisms were again generally somewhat higher in pyrophosphate adjusted with sulfuric acid than in pyrophosphate adjusted with HCl. Pyrophosphate adjusted with nitric acid showed a slightly lower total number and coliform index than did the other two at the start, but by the end of the seven days both indices were higher than in either of the other two pyrophosphates.

The results for sodium and potassium orthophosphate were somewhat variable. However, after four days of incubation the total number of bacteria in the potassium salt exceeds the total number in the sodium salt. Except for one jump in the coliform index in the

TABLE 14.—VIABILITY OF BACTERIA IN RAW-WATER SOLUTIONS OF VARIOUS PHOSPHATE SALTS

Phosphate Ion Equivalent to 1% Hexametaphosphate	Period of Incubation: 1 Day Bacteria per 100 ml.	1 Day Coliform per 100 ml.	2 Days Bacteria per 100 ml.	2 Days Coliform per 100 ml.	4 Days Bacteria per 100 ml.	4 Days Coliform per 100 ml.	7 Days Bacteria per 100 ml.	7 Days Coliform per 100 ml.
0.73 gram $Na_4P_2O_7$ adjusted with HCl	25,000,000	10,000	180,000,000	1,000,000	130,000,000	3,400,000	130,000,000	1,000,000
0.73 gram $Na_4P_2O_7$ adjusted with H_2SO_4	31,000,000	37,000	190,000,000	1,000,000	180,000,000	4,000,000	160,000,000	1,000,000
0.73 gram $Na_4P_2O_7$ adjusted with HNO_3	26,000,000	1,000	150,000,000	400,000	280,000,000	1,000,000	400,000,000	1,000,000
1.0 gram $Na_6(PO_3)_6$ made from $NaPo_3$ adjusted with NaOH	39,000	10,000	39,000,000	1,000,000	65,000,000	1,000,000	100,000,000	7,000,000
0.21 gram $(NH_4)_2HPO_4$	660,000	10,000	3,600,000	10,000	20,000,000	7,000	30,000,000	7,000
0.22 gram KH_2PO_4 adjusted with NaOH	5,000,000	10,000	21,000,000	40,000	18,000,000	10,000	7,100,000	7,000
0.22 gram NaH_2PO_4 adjusted with NaOH	6,900,000	10,000	22,000,000	10,000	5,000,000	10,000	4,900,000	7,000

Average number of bacteria at start = 44,000 per 100 ml.
Average number of coliform organisms at start = 10,000 per 100 ml.

potassium salt after two days of incubation, the coliform indices were practically the same. The ammonium salt solutions gave much lower results for both total numbers of bacteria and coliform index, but the total number of bacteria after seven days of incubation exceeded the total number in either of the other two salts at any other time. The coliform index never exceeded the coliform index of the other orthophosphate solutions but did equal it after seven days of incubation.

Conclusions. Apparently a 1% solution of almost any phosphate, under proper conditions, in raw water will produce a stimulation of bacteria at summer temperatures. Changes of the cation produce some variations as do changes in the structure of the phosphate. In general, the degree of stimulation decreased in the following order: pyrophosphate, orthophosphate, and hexametaphosphate. However, this order varies with the length of incubation. Phosphates are being used at the present time as detergents for dishwashing and for water softening. It is hoped that the results presented will place a check on indiscriminate use of phosphates in these situations, as well as in any others of public health significance associated with the growth of bacteria in phosphate solutions, until proper determinations have been made of the effects of these phosphates on bacterial growth under field conditions. This statement does not imply that some of the phosphate detergents now on the market are not of great value if properly used.

SUMMARY

1. The results presented indicate that almost any phosphate in a raw water of the type to be found near Lawrence, Mass. will increase the count of bacteria.

2. Pyrophosphates gave higher total counts of bacteria than did ortho or hexametaphosphates and also extremely high coliform indices.

3. Adjustment of pyrophosphates with sulfuric acid led to higher results than did adjustment with hydrochloric or nitric acids.

4. Addition of nitrogen either as nitrate or ammonium radicals produced a lower total count in the early periods of incubation but a higher total count at the end of the 7-day period than did other salts of similar character.

5. Hexametaphosphate solutions produced much lower total

counts in the earlier periods of incubation than did either ortho- or pyrophosphates, but after seven days of incubation, the total count was higher than in orthophosphate but not as high as in pyrophosphate.

6. Addition of chloride ions produced slightly higher results.

7. There was very little difference between the effects of the sodium and potassium ions.

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III. Viability of *E. coli* in a Solution of Sodium Pyrophosphate and Other Diluents

As shown in Part II of this paper, pyrophosphate added to raw water produced tremendous increases in the bacterial flora of the raw water. It was the purpose of the present experiment to determine the effect of solutions of sodium pyrophosphate in distilled water as compared with sodium orthophosphate for short term periods on a culture of *E. coli*.

Two concentrations of orthophosphate were selected at the start in order to determine in what range the effect would be most pronounced. One percent stock solutions of sodium orthophosphate (NaH_2PO_4. H_2O) and its chemical equivalent (3.2%) of sodium pyrophosphate ($Na_4P_2O_7$. 10 H_2O) were made with distilled water. The sodium orthophosphate solution was adjusted to a pH of 7.1 with sodium hydroxide and the sodium pyrophosphate solution to the same pH with sulfuric acid. Each of these solutions was diluted 1 to 10 and 1 to 100. The final concentration therefore, was 0.1% and 0.01% of orthophosphate, and 0.32% and 0.032% of pyrophosphate. It was felt that chemical equivalents would be of more value for comparative purposes than would direct percentage equivalents, since it was believed that any reactions would probably be of a chemical or physical nature.

Three bottles containing 100 ml. of each of the two dilutions of

both salts were autoclaved at 10 psi. of steam pressure for 20 minutes. Upon precipitating portions of the autoclaved pyrophosphate solutions with silver nitrate, it was found that there was a very slight tinge of yellow to the pyrophosphate precipitate indicating that while small amounts of the pyrophosphate had broken down to the orthophosphate, the greatest percentage was still there as pyrophosphate.

In order to create a specific time interval between all twelve bottles, they were inoculated at one-minute intervals. This same interval of time was maintained whenever aliquot parts were taken from the twelve bottles. The culture used for inoculation was a 7-day slant culture of *E. coli* isolated in routine work at the Lawrence Experiment Station. All plates were poured with lactose agar immediately after inoculation in order to stop promptly all further reaction with the phosphate solutions. The results obtained are summarized in Table 15.

TABLE 15.—VIABILITY OF *E. coli* IN DISTILLED-WATER SOLUTIONS OF SODIUM ORTHO- AND PYRO-PHOSPHATES

(Number of *E. coli* per ml.)

Concentration of Phosphates	Time in Minutes						
	Start	30	60	120	210	330	450
NaH_2PO_4 0.1% plus NaOH; pH 7.2	440	370	340	203	110	66	38
NaH_2PO_4 0.01% plus NaOH; pH 7.2	450	420	400	170	70	35	18
$Na_4P_2O_7$ equivalent of 0.1% (0.32g/100ml.) plus H_2SO_4; pH 7.1	460	400	330	240	220	170	140
$Na_4P_2O_7$ equivalent of 0.01% (0.032g/100ml.) plus H_2SO_4; pH 7.1	450	440	420	390	390	320	290

It will be noted that the lower concentration of pyrophosphate maintained bacterial numbers far better than did the higher concentration of pyrophosphate or either concentration of orthophosphate. The higher concentration of sodium pyrophosphate caused a sharp decrease in numbers of bacteria for the first two hours, after which the decrease was more gradual. The lower concentration of orthophosphate caused the numbers of bacteria to remain approximately

parallel to the lower concentration of the pyrophosphate for about one hour, after which there was a sharp drop for about 1½ hours and then a more gradual decrease for the remainder of the 7½ hours; the total count at the end of the 7½-hour period was lower than in any concentration of either phosphate. The higher concentration of orthophosphate caused a rather rapid decrease in the number of bacteria throughout the 7½ hours. At the end of 7½ hours, the total counts ranked as follows in decreasing order: 0.032% pyrophosphate, 0.1% orthophosphate, 0.01% orthophosphate.

In view of the excellent survival of bacteria in the lower concentration of pyrophosphate solution, it was decided to find the optimum concentration of pyrophosphate for the culture in use. The following concentrations of pyrophosphate were prepared 0.16%, 0.032%, 0.0032%, 0.00032%, and 0.000032%. The experiment was carried out in a manner very similar to the previous experiment. The results obtained are shown in Table 16.

TABLE 16.—VIABILITY OF *E. coli* IN DISTILLED-WATER SOLUTIONS OF SODIUM PYROPHOSPHATE

(Number of *E. coli* per ml.)

Percent of Sodium Pyrophosphate	Time in Minutes						
	Start	30	60	120	210	330	450
0.16	430	420	420	410	405	380	365
0.032	415	420	420	405	340	225	145
0.0032	370	290	230	89	32	11	0
0.00032	370	110	31	1	0	0	0
0.000032	380	63	13	0	0	0	0
	Start	30	60	120	180	330	450
0.22	215	206	207	193	203	177	171
0.19	212	196	207	195	195	181	163
0.16	212	216	202	203	178	167	162
0.13	213	209	198	184	182	188	173
0.10	216	211	199	203	191	198	185

The 0.16% solution of pyrophosphate gave the best survival. For some unknown reason the 0.032% solution which followed the 0.16% solution for 2½ hours dropped rather rapidly after this period. It

was felt that the optimum concentration would be some concentration nearer 0.16% than 0.032%. Consequently the following concentrations of sodium pyrophosphate were used: 0.22%, 0.19%, 0.16% 0.13% and 0.10%. The 0.10% solution seemed slightly the best for maintenance of bacteria. In the belief that 0.10% was as near the optimum as possible, the results obtained for this concentration were accepted as optimum for survival of this culture.

The final experiment was a comparison of several diluents: (1) The optimum concentration of pyrophosphate (0.1%); (2) phosphate dilution water (2); (3) physiological saline; (4) B.O.D. carbonate water (2); and (5) Lawrence tap water. The remainder of the experiment was similar to the previous experiments. Results are given in Table 17. This table shows that for holding this culture of

TABLE 17.—VIABILITY OF *E. coli* IN VARIOUS DILUENTS
(Number of *E. coli* per ml.)

Diluent	Time in Minutes						
	Start	30	60	120	180	300	450
0.1% Sodium Phosphate Orthophosphate Dilution Water	7700	7300	6500	6100	5700	5100	4400
	6600	3600	1300	183	27	0	0
Physiological Saline Solution	7100	4900	3100	1260	470	76	6
B.O.D. Carbonate Water	6600	3800	1200	54	4	0	0
Tap Water	7100	7000	6800	5600	3600	1640	570

E. coli for a period of several hours 0.10% sodium pyrophosphate was far superior to any diluent tested. Lawrence tap water was also very satisfactory for periods up to 1½ hours. The other diluents did not appear to be as satisfactory.

DISCUSSION

A 0.10% distilled-water solution of sodium pyrophosphate enabled one culture of *E. coli* to survive better at room temperature than did Lawrence tap water, orthophosphate dilution water, physiological saline solution, or B.O.D. carbonate water. Unfortunately, circumstances did not permit this work to be continued with other organisms. However, if the stability of other bacteria in this diluent is as satisfactory as the stability of *E. coli*, this diluent might be valua-

ble in the maintenance of cultures requiring several hours for transportation to the laboratory. In drinking glass examinations, for example, where, at times, several hours elapse between collection of the sample and the laboratory examination, this diluent might give a more accurate picture of the bacteria found on the glass at the time of swabbing than would other suspending fluids.

THE OFFICE OF WAR UTILITIES' PROGRAM FOR COOPERATION WITH THE WATER INDUSTRY

BY ARTHUR E. GORMAN*

[*Read September 28, 1943.*]

A year ago I had the pleasure of presenting a paper at the annual meeting of this association on the subject of *Water—A Critical War Material.* To use a familiar New England expression "much water has passed over the dam" since then. I appreciate your kind invitation to return this year to report on developments in water supply from the viewpoint of the Office of War Utilities and its responsibilities to the water industry and the nation's war effort.

I should like to review certain important developments of the past year and to discuss with you as representatives of the water industry in this region some of the problems of mutual concern and interest that confront us in maintaining adequate water supply and service for war production, for military purposes, and for essential civilian needs.

You will recall that last year at this time we were actively discussing the development of a mutual aid plan to assure an adequate supply of materials to meet emergencies, should water systems be damaged by enemy action either through sabotage or aerial bombings. The acute shortage of cast-iron pipe and other important water supply materials and equipment was a matter of real concern. Now surplus inventories are being exchanged freely between utility systems. This exchange is more the product of a coöperative effort to conserve for war production than for mutual aid during emergencies; the risk of damage by enemy action is generally recognized as considerably reduced, and the critical shortage in cast iron pipe no longer exists. These changes in conditions affecting the water industry are typical of the tempo of our national life during this war. It is inevitable that more changes will be experienced; and we should be prepared to meet them.

*Director, Water Division, Office of War Utilities, War Production Board.

Early this year, the intensive war construction program—with certain notable exceptions—reached its final stage. Our war program was passing through a re-adjustment stage—one between the end of the construction period and the getting under-way of the phenomenal production program. As a result, in some areas the impression gained credence that such critical materials as steel and copper were no longer tight; and that the War Production Board should relax priority restrictions on projects, materials, and equipment for civilian construction on a wide front. Nothing could have been further from the facts. There is no indication that steel and copper will be available for projects other than essential ones for many months. In fact, as the war potential has increased, the demand for these basic metals in war production has greatly exceeded output and fabricating capacity. We are reaching the period of maximum production which will continue until the war ends, being subject to such fluctuations in demand as military necessities dictate.

Water and other utility services are vital to war production; therefore, they must be maintained at all costs. The water industry has responded splendidly in meeting its war responsibilities. In many areas, necessary water utility expansions to meet war demands were phenomenal, but they were carried to completion in the face of many difficulties; and much has yet to be done. Of special interest are the following three projects recommended by the War Production Board in order that theatened deficiencies in water supply and service might be prevented in industrial areas of vital importance to the war program:

1. A pumping station, two temporary reservoirs, and 35 miles of canals were constructed to bring over 50 mgd of water from the San Jacinto River into Baytown and the Ship Canal industrial areas in the vicinity of Houston, Texas. This project was essential as a war measure to meet the extraordinary demands for water in connection with the aviation, gasoline, and artificial rubber programs. Additional ground water supplies in the area could not have been obtained without seriously jeopardizing water supply to the City of Houston and established industries in the metropolitan area.

2. The development of a new well field south of Hamilton, Ohio, and the construction of about 20 miles of 30-inch diameter reinforced

concrete transmission main and a 15-mg reservoir to supply water to a large airplane engine plant in Lockland.

3. The construction within two months of a 160-mgd capacity pumping station to improve water service this summer to important war industries within and outside the northern limits of the Detroit water system. With the completion of this project, it was possible this summer to deliver Detroit water during hours of low consumer demand to a 45-mg open storage reservoir owned by the City of Highland Park and to repump into those areas of the Detroit System where pressure deficiencies had existed and thus meet all peak load demands. Pumps to make this project possible were loaned by the City of Philadelphia from projects that had been suspended because of a shortage of materials.

These projects were all federal financed and constructed by the Federal Works Agency on recommendation by the War Production Board. They are examples of effective coöperation between federal and city officials to meet unusual situations where existing water facilities were over-taxed and where adequate water supply and pressure was essential for war production purposes.

From the standpoint of utility operations, perhaps the most significant development of the past year was the organization, in February 1943, of the office of War Utilities, with J. A. Krug, Director. Mr. Krug, before being promoted to the position of Program Vice-Chairman—which he still holds in addition to that of Director of the Office of War Utilities—previously had been Chief of the Power Branch. Within the Office of War Utilities five major divisions were created. These were Power, Natural Gas, Artificial Gas, Water, and Communications.

The prime responsibility of the Office of War Utilities is to see to it that utilities are provided with the necessary materials and equipment to maintain adequate service to meet all essential war production, military, and civilian requirements. In turn, each of the Divisions in the Office of War Utilities must discharge this responsibility to the respective utility it represents. That is why the Water Division is so vitally interested in your problem. It is why I am so pleased to have this opportunity to discuss our Division activities with you at this meeting.

The new Office of War Utilities was made one of the seventeen claimant agencies of the War Production Board with the right to submit its own requirements program for allotments of materials under the Controlled Materials Plan, and to issue, without further review, authorizations for utility constructions and the allotment of materials. These important advantages made it possible to effect important administrative changes that have resulted in much more prompt and direct actions on project applications than had heretofore been possible.

The Water Division is charged with the responsibility for mobilizing water supply for industries, military, and naval establishments, and essential civilian uses, and for recommending necessary measures to secure adquate water supply for these purposes. The Division is now organized into two major sections. These are called the Water Supply and Materials Distribution Sections. The technical staff has been increasing and today consists of twenty-eight experienced water works engineers. Each is interested in helping you to maintain water utility standards and service.

The Water Supply Section has the responsibility of determining water utilities facilities and requirements to maintain adequate water supply and service and of making such recommendations as are necessary to maintain this service for all essential war production purposes.

For administrative purposes within this Section, the nation has been divided into six regions with an area engineer in charge of each. All project applications, with the exception of certain small ones involving water main extensions, are referred to this engineer for review and a recommendation concerning relative essentiality. The Water Supply Section with its area engineer is the principal contact unit between the operators of water utility systems and the Office of War Utilities. The area engineer and his assistants are your friends. They want to know you and what your problems are in order to be of most help in maintaining water supply and service during this war. You will be pleased to know that the area engineer for Region No. 1 comprising New England and New York State is a member of this Association and a life-long resident of New England—Bayard Snow.

The Materials Distribution Section reviews applications from the standpoint of availability of materials and equipment, and com-

pliance with limitation orders. It also issues the priority and makes the allocation of controlled materials. All water project applications from utilities should be filed on WPB Form 2774. Complete instructions in regard to preparing this form and supporting the application by supplemental technical information were mailed to all utilities within the last month.

The Facilities Service Unit of this Section is in contact with manufacturers in regard to available water works equipment and cooperates with them in obtaining allocations of controlled materials. Engineers of this Section review projects for the purpose of aiding applicants in obtaining materials and equipment from the excess inventories of other utilities, industry divisions, or claimant agencies, and follow closely the construction of all important projects to see that deliveries of essential materials and equipment are made in time to meet construction schedules. The Section interprets limitation orders pertaining to water utilities and will administer any WPB limitation order that the Division may originate in the interest of maintaining adequate water supply and service for essential war purposes.

The designation of the Office of War Utilities as a claimant agency in the War Production Board under the Controlled Materials Plan is prime recognition of the importance of utilities to war production and for essential military and civilian needs. Under this plan, which went into full effect July 1, 1943, this Office now receives, in quarterly allotments, a definite share of the available steel, copper, and aluminum produced in this nation and is held strictly responsible for its allocation of these materials to the nation's utilities. CMP has done much to correct the difficulties previously experienced in tion and for essential military and civilian needs. Under this plan, the recipient of an allotment of controlled materials for any quarter is assured of delivery during that quarter. Allotments are made to manufacturers as well as to applicants for construction projects. Under the old priority system a holder of a low priority was never sure of delivery dates because of inability to forecast how many higher priorities might be issued after receipt of his. These uncertainties worked hardship both on the applicant and materials producer.

While the general policies of the Office of War Utilities are uniform for all utilities and each system may serve substantially the

same consumers, in some aspects, the relationships of the services rendered by these utilities to the war production program may vary widely, and their respective material and equipment requirements may differ considerably. For example, power utilities require large amounts of copper and little cast iron, while water utilities use relatively small amounts of copper and large amounts of cast iron.

The requirements of utilities for materials and equipment fall into two major categories. First, those for maintenance, repair and operation and, second, those for extensions and betterments. The policies of the Office of War Utilities in regard to priority ratings for materials and equipment for these requirements are consistent and definite. Even though war demands for materials are heavy, essential utilities will be supported to the fullest extent in maintaining essential plants. There is no material economy in deferring necessary plant maintenance or repairs; in fact, such deferment may result in need of early replacements at a critical period during the war, which would be directly in competition with war production. Shortsightedness along these lines should be avoided.

To assist utilities in maintaining plant with a minimum of reference to the WPB for priority assistance, a special order known as U-1 Order was promulgated on February 24, 1943. It is the successor to P-46 Order of the former Power Branch. It was broadened and liberalized in subsequent amendments. Under this Order, as amended September 22, 1943, utilities are given the right to extend an AA-1 priority and automatic allocation of controlled materials for maintenance, repair, and operation, except for material used for extending lines to consumers. For this material, an AA-3 priority authorization has been granted.

This Order is a very important one and should be understood by all in responsible charge of materials, equipment, and supplies for utilities. Because the Order controls materials for maintenance, repair, and operation for three utilities—power, gas, and water—responsibility for its administration within the Office of War Utilities is centralized in an Administrator, who clears with Division Directors. There have been discussions of the wisdom of separate U-1 Orders for each utility to be administered within the respective Divisions, but

this plan has administrative complications as well as advantages and the over-all order is still in favor.

There is clear evidence that many water utilities are not taking advantage of the provisions of U-1 Order to maintain plant. Altogether, too many water utility operators are submitting applications to Washington for work already permitted under the U-1-Order. The recently announced U-1-f amendment makes it unnecessary to obtain permission for extensions to certain consumer premises where the net cost of material is less than $1,500. You will be pleased to learn that this amendment has just been revised removing the 100 pound pressure limitation in the use of steel service pipe and increasing the weights of cast-iron pipe which may be used for extensions to serve consumers. Under the amendment, any kind of pipe except copper may be used for services. This is to make it possible to maintain sound minimum practice in installing water pipe of adequate size so that service for fire protection may not be hampered. Earlier in the period of the war when cast iron pipe was tighter, it was necessary to place very close limitations on pipe sizes for such connections.

During the last year, several changes in limitations on water inventories were made. The reduction to 60% of the 1940 base, which went into effect October 10, 1942, apparently hurt none of the water utilities. But the further reduction to the basis of a current year's inventory included in the original U-1 Order resulted in strong objections by water utility operators. Therefore, the Order was amended on May 31, 1943, to revert to the old P-46 base. Again, with few exceptions, the utilities seem satisfied. It should be remembered that the Order provides for increases in base on pumping plant and source of supply materials and equipment, proportionate to increases in production; and of course, in exceptional cases adjustments in base can be made to establish equity.

The policies of the Office of War Utilities are definitely toward elimination of unnecessary paper work. The record of utilities in the conservative use of critical material is good.

Recently, a considerable number of water utility operators have recorded their disapproval over the limitations in the use of copper under Order M-9-C administered by the Copper Division; also, by the plan of the Copper Recovery Branch to redistribute and impound

for scrap the copper reserve pipe held in excess inventory. The Water Division, in presenting the case of several water utilities for special exemptions under this Order has always found the Copper Division representatives sympathetic to your problems, but in the light of the existing tight situation with regard to copper that Division has been firm in its opinion that copper tubing in excess inventory was so urgently needed in the interest of the war effort that relaxations in the Order, other than those for repairs and for goosenecks, should not be made. While the Water Division has no jurisdiction over this copper limitation order, it is always ready and willing to coöperate with any water utility, where, because of special conditions involving safety and public health, it feels that special exemptions from the Order are warranted.

In regard to new construction and major extensions of existing properties, the strict policy of limiting materials for this work to projects essential to war production and military and civilian needs cannot be relaxed so long as the material, manpower, and transportation situations continue to be tight. We must, therefore, continue to request water utilities to defer all possible major extensions and betterments. I am sure utility operators will understand and accept these limitations which may mean that for the duration we shall not be able to meet long established and normally excellent standards that call for considerable duplication of equipment and liberal standby service.

As to special construction and equipment for protection against potential war hazards, the importance of maintaining reasonable fire protection facilities is obvious and is being supported by priority assistance. In the past, in connection with new housing, there were instances where, because of the tight material situation, the water service installations made were not wholly adequate for proper fire protection.

The Water Division is now engaged in several activities of special interest to all water utilities. During the last two months, in cooperation with the United States Public Health Service, engineers of the Division have been contacting water utility operators to obtain information concerning current facilities and material requirements for maintenance and plant extensions. The prime objective of this

survey was to obtain specific data to support the Division's request for quarterly allocations of controlled materials during 1944. It is planned to continue these surveys until sufficient basic data have been obtained on facilities and requirements in all cities where war requirements are especially important. This will also provide a wartime pattern on the basis of which material requirements for the entire water industry may be forecast with reasonable accuracy. The Division has enjoyed the fullest coöperation from water utility operators in connection with these surveys.

Starting September 15, the War Production Board launched a nation-wide conservation program with the coal, petroleum, and transportation industries participating. Task Committees of the various industries coöperating in the campaign met late in July and outlined practical working programs for their industries. The report for water utilities has been mailed to all water utilities in the nation. The Wartime Activities Committee of the American Water Works is developing a conservation program booklet to be distributed to water utilities as a guide in organizing and carrying out the conservation campaign with their consumers through available local channels. The over-all conservation program is receiving national publicity through news releases, radio campaigns, and advertisements in various media. The campaign will be a continuing one with special seasonal emphasis. The water conservation campaign will be focussed toward elimination of waste and non-essential uses of water. The appeal will be to all consumers—domestic, commercial, and industrial—to eliminate fixture leaks and wasteful practices; also, to municipalities to check waste through leaking fire hydrants, drinking and display fountains, and other fixtures where waste often occurs through carelessness. Conservation of this type will save fuel, power and chemicals. The savings that can be effected through conservation or waste elimination are much greater than any of us realize. We do not want to lower American standards of living by unnecessary restrictions on all legitimate uses of water, but we do want to "use water usefully."

Seasonal water conservation campaigns will be directed toward the reduction of peak load demands. We are hopeful that this reduction may reach as high as 15 percent. If it does, it should permit the deferment of a very considerable amount of normal plant expansion

projects calling for critical materials and equipment urgently needed in maintaining war production.

I am sure that this conservation campaign will be given the fullest support by all New England water utilities. For maximum effectiveness, we shall coördinate our water conservation program with those of the power, gas, and communications utilities. Each utility operator should acquaint himself with the conservation program being developed by other utilities in his city or town.

Since the war began in the fall of 1939, with some local area exceptions, rainfall throughout the nation has been above normal. We all hope that this fortunate state of affairs continues. But based on the historical record, the probability of continuance of abnormal rainfall is not good. Rather, drought conditions are to be expected.

Without adequate water supply, our war industries could not function as they must if we are to win this war with a minimum loss of life. Even periodic short-term interruptions of water service could seriously interfere with important war production, for our schedules of products are highly integrated, and a delay of parts due to operating interferences in one area may affect assembly of important war equipment elsewhere. Water shortage to housing areas would have a serious effect on labor turn-over; water for irrigation is essential to the nation's food program; fire risks are much greater in relation to war production than most normal industry operation. Finally, and of profound importance, is the basic fact that there is no substitute for water as there is for other utility services.

For these reasons it is essential that all water utility operators appraise their system in regard to its basic points of vulnerability in case of prolonged drought; and be prepared with an emergency plan of action to meet essential war loads in case of drought. In case of a wide-spread drought the Office of War Utilities would be required to seek special allocations of materials and equipment to meet the contingencies which would arise.

There are areas in Louisiana, Mississippi, and East Texas which have experienced serious drought conditions this summer. Several large water projects in the Mountain and Pacific Coast areas each of which if constructed would require large tonnage of steel have been deferred since the war started, because favorable rainfall conditions

have permitted existing sources to produce an adequate supply. Should rain and snowfall on these water sheds be sub-normal this winter, the necessary materials must be released for water supply construction, but this action will lessen war supplies by that much.

In New England, the back-log of impounded water is relatively small in comparison with the west coast supplies because of the wide difference in annual rainfall. Therefore, if a prolonged drought were to occur in New England, the effect could be very serious. Without wanting to be an alarmist in this situation, it does appear prudent for us all to consider the possibilities of drought emergencies and to prepare a plan of action to meet them if they should develop. The Office of War Utilities will appreciate your coöperation in this important program of preparedness.

In conclusion, it is my firm opinion that the water industry can be proud of the way it has maintained water supply and service to supply the greatest war effort this or any nation has put forth. But there is no room for complacency, because with a long war the strain on the water utilities will be a heavy one. We must continue to be alert and resourceful. To summarize:

1. The Office of War Utilities is organized to serve you. Its Water Division is anxious to know your war-time problems and to help in any way possible in meeting war production and essential military and civilian needs.

2. All projects that can be deferred should be, because the materials, manpower, and transportation situations are serious. The cast-iron situation has improved, but steel, copper, and aluminum are in great demand for war production and will continue to be tight.

3. Water utilities should maintain plant in first class condition. The OWU through its U-1 Order has given utilities ample authority to obtain materials necessary to maintain plant. There is evidence that water utilities are not taking full advantage of the opportunities this order affords. Too many project priority applications are still being referred to Washington. Every water utility operating executive should be thoroughly familiar with this Order and its recent amendments, especially U-1-f which reduces substantially the necessity of filing applications for minor constructions and consumer service connections.

4. The nation-wide conservation program being carried out by the WPB deserves the fullest support of all water utilities and should be integrated locally with the conservation program of related utilities.

5. The potential hazard to war production, should water utilities be faced with operations during a prolonged drought, is a serious one. Every water utility should appraise its plant to determine points of vulnerability in case of drought and plan what special priority actions should be taken to obtain necessary materials and equipment.

Discussion

H. Lloyd Nelson.* I am not going into many of the details of the conservation program that Mr. Gorman has mentioned, but I want to give you the background for the necessity of a conservation program particularly at this time.

The higher officials of the War Production Board and other governmental agencies in Washington, knowing what the war plans were, began to worry about the situation that might be encountered during the coming winter. Mr. Donald Nelson, Chairman of the War Production Board, Mr. Harold Ickes, Secretary of the Interior, Petroleum Administrator for War, and Solid Fuel Administrator for War, and Mr. Joseph Eastman, Director of the Office of Defense Transportation, discussed this problem and decided that they would prefer, if possible, to handle the matter on a purely voluntary basis. They felt that the patriotism of the consumers of coal, petroleum, electric power, water, gas, transportation, and communications in the country would lead them to participate in a voluntary conservation program in order to make sure that we shall have enough of these services and basic materials to carry us and our armed services through the coming winter.

The campaigns in Sicily and Italy involve additional loads on the resources of the United States to supply the necessary coal and fuel oil for operating the railroads and airplanes in those areas. As many of you know, the coal for Italy formerly came from Germany. Production is running approximately 600,000,000 tons annually, while in Great Britain only about 30,000,000 tons are produced annually.

*Principal Engineer, Office of War Utilities.

The entire fuel supply for the Mediterranean area will, therefore, have to come from the United States. This involves manpower, transportation, and shipping, all of which are very tight and very critical.

Donald Nelson has said that he doesn't want to put a hair shirt on the American public, but if it is necessary to ration coal, as we do fuel oil and gasoline, it will be done, but as a last resort. We would not like to have to go into the necessary great details, the paper work, and so forth, trying to ration coal. So the people of the United States are being asked this winter to tighten up their homes against heat loss, to learn how to fire their furnaces properly, and not to overheat their rooms and then open the windows in order to cool them down. It is estimated that in the eighteen million homes in the United States heated with coal, there could be saved a ton each, which would mean 18,000,000 tons of coal saved in house heating alone by a simple program of conservation and of stopping waste—not asking anyone to do without anything that he needs, but simply stopping waste.

Water, of course, requires pumps as well as other materials, and it requires chemicals for treatment. Pumping involves power of some kind. Our power comes from coal or oil, usually. The electric power used in the home requires these basic fuels. So that the public is being asked to turn off lights they do not need, not to waste the electric power, not to leave the refrigerator door standing open for unusual lengths of time, not to put hot foods in the refrigerator but to cool them off first. There are many hundreds of ways of stopping waste in order to enable us to get through without rationing.

The program to be followed by the water utilities naturally falls into two different general classes. One is the general, day in and day out, all year around from now on for the duration, program to repair leaky faucets and fixtures, to stop letting water run unnecessarily and to avoid wasteful sprinkling.

The other program, as Mr. Gorman has mentioned, is the special seasonal program that would naturally be run in the spring and fall, to provide a smoothing out of the demand for water under these great peaks and thus save valuable critical material that would be necessary to meet the peak demands, by requesting customers to sprinkle on

alternate days in different sections of the city, and at off peak hours, whichever will fit in best with individual system requirements.

The water conservation campaign is divided into three different parts. The first deals with what domestic customers can do. The second concerns what big industrial users can do to prevent waste of water. The third concerns itself with what water works can do in the operation of their plants in order to conserve water. Find out, ask the consulting engineers, the pump manufacturer, the boiler manufacturer, to help you make your plant operation more efficient, so that you can cut down on your own use of fuel, whether it be electric power, coal, or oil. There are ways in most plants by which you can effect savings that will be money in your own pockets. Then you can proceed with leakage surveys, to discover and stop leaks in the distribution system, or in the plants, or in the hydrants, as Mr. Gorman has mentioned. As I look at the program from those three different angles, I think you will all agree that much can be done that will be helpful.

The American Water Works Association, in preparing its manual, made some suggestions for advertisements that can be printed and included with bills to consumers, for radio talks, or for posters, that can be reproduced for distribution. I understand that the handbook will be ready within a week or two and will be mailed to towns serving approximately 10,000 people or larger populations, with a little note pinned on stating that there are no funds available for this cooperative effort—and requesting that the actual cost of the book be remitted. I know that you will be glad to coöperate to reimburse the Association for the cost of getting out this material. Those who do not have the booklets mailed to them can, by writing to Harry Jordan, find out what the cost is and secure a copy for their use.

I have just had handed to me a card prepared by the Industrial Chemical Sales Division. It reads as follows:

"It takes men and materials to bring water to your tap. Don't waste water. Water is one of the basic essentials of life and of war. Without water, planes, guns, tanks, ships, etc., cannot be produced. There is plenty for essential use—drinking, cooking, washing, cleaning, manufacturing purposes—but not a single drop for waste!

It is our patriotic duty to conserve it.

STOP letting water run needlessly.

STOP leaks in faucets and fixtures.

STOP nonessential use of hose, and above all avoid creating fire hazards from accumulating papers and trash in cellars and attics. You save water when you prevent fires.

Aid the war effort; use water wisely.

Three ways to help conserve water:

Stop dripping faucets;

Stop running water you do not use;

Stop reckless use of hose."

Each water superintendent is requested to get in touch with the heads of the gas utility, the electric utility, the transportation system, the local coal dealers' association, the local fuel oil dealers' association in his city and form a coöperative local committee to make sure that all campaigns are run in unison and that all these services cooperate and work together.

The electric utilities are all doing a nice job. They are spending money to tell everyone that they are coöperating with the other utilities and services to save power, fuel, transportation, and all vital materials by promoting a broad conservation program in an endeavor to avoid waste.

Many of the municipally owned utilities have an excellent opportunity, because of local interest in the city governments, to get a lot of free publicity. In the August 15 issue of one of the Philadelphia papers, in the Sunday magazine section, the water bureau was able to secure six pages explaining its water conservation program. It showed various ways in which waste of water can be stopped.

There is nothing in this program to ask anyone not to use water that is needed, or not to use water for essential purposes. The entire program is developed on the basis of stopping unnecessary and wasteful use of water.

Probably in a few months, after the campaign has run a while, you will get a letter requesting you to make a report to Mr. Gorman on the results of your program. We would like to know what you estimate the program saved you in fuel, chemicals, materials, equipment, manpower, deferred capital improvements, and what you secured in the way of improved service to customers, and the type of customer coöperation that was accorded to the local program. In making up these estimates, it is understood that you must base them on what you think the load on your system would have been if you

had not had the program. We are assuming that you will figure in new loads that have come on to the system since last year in order to make comparisons with the water used during the corresponding period of the year before.

I want to close by stating that, now as the tempo of the war effort is increasing so greatly, this is not the time to rest on our laurels, when we have the enemy wabbling, but it is the time to jump in and soak him again. Let us all together use our very best efforts to make our coöperative program go over in the good old American way.

CHAIRMAN CLARK. I understand that the restrictions on steel pipe for water services are diminished.

MR. GORMAN. Yes, the 100-psi limitation is off. The quantity of materials now permitted to be used is based on the assumption that you have a 6-in. main in the street and that your extension to the next lot is 50 ft. I think you will all agree that under present conditions. this is very liberal. Of course we would like to see you use as much cast iron pipe as you can for these extensions, because at the present time it is less critical than steel. But you may have special conditions of installation for which it is essential that you have steel. In that case we want you to use what is needed. It is all a matter of using the material that is least critical and that will give the equivalent service.

CHAIRMAN CLARK. If we want to replace a worn out 2-in. steel line with cast iron, are we allowed to put in a 6-in. pipe?

MR. NELSON. Under U-1 if you are replacing something that is no longer of possible use to you with material of the same capacity and design and size, there is no limitation on the dollar value of that replacement outside of the total dollar value of the withdrawal that you are permitted under the order for that class of material. However, if you want to increase the size, you are permitted under the Minor Capital Addition clause in U-1 to replace up to the cost of replacing the present size in the system and an *additional* $1500 worth of material in underground construction. In other words, if you had a thousand feet you would find out what it would cost to get

a thousand feet of 2-in. steel pipe today with which you could replace the worn out 2-in. line, and then if you can for $1500 more than that amount get 6-in. cast-iron pipe, you can put it in as a minor capital improvement, because the increase in capital account in that case would only be $1500 (underground construction). Above ground the limit is $500.

MR. GORMAN. A case in Milwaukee might be of interest. In connection with a house conversion program of FHA, several single residences were remodeled into three, four, or five apartments. It was reported that the ⅝-in. service connection for the residences would not be adequate to maintain minimum service standards because of health hazard involved by reduction of pressure. Under such circumstances, the owner could increase the size of the service connection or put in another one if it were necessary. You are permitted to maintain minimum service standards to meet the changing conditions resulting from the impact of war.

MR. NELSON. Mr. Gorman mentioned in his paper the fact that it is now possible to use copper for goosenecks. That is not true, however, by virtue of any ruling that gives you automatic authority to use it. Mr. Gorman has been successful in convincing the Copper Division that in many cases where you cannot use material such as lead because of water or soil conditions, it would be to the best interest of the war effort to permit utilities to use copper service pipe for making goosenecks not over 18 in. long, and they have agreed with us verbally that if you apply by letter to the Copper Division, reference M-9-C-4, War Production Board, Washington, D. C., giving them your estimate of the amount you wish to install and stating the fact that you have the copper tubing in stock, available for use, in response to such a letter you may secure permission to use the copper tubing you have in stock for such gooseneck installations. They have agreed that they will give such permission, but it is not automatic. You just can't go out and do it without asking.

In regard to the Copper Recovery Corporation's plan for picking up the frozen stocks of copper service pipe of water utilities, and also such stocks in the hands of the gas industry we were fortunate in having issued on September 21 Direction No. 30 to CMP Regulation

No. 1, which provides that anyone manufacturing copper service pipe may not manufacture such pipe of the types K, L, or M on any orders without getting permission from the Copper Recovery Corporation. This means that the Copper Recovery Corporation will have an opportunity on such orders to check their records of material that you have reported to them as in stock and help you sell that copper tubing at the regular market price without any loss to you, for use in the war effort where it is most needed, as on shipboard. They will help you sell all they can at regular market prices before they endeavor to force you to turn the balance of it over at 18 or 24 cents per lb. as scrap.

HORACE J. COOK.* In the letter that Mr. Gorman speaks about, mention is made of taking advantage and doing as much as we can in maintenance and repairs. The fact is that we cannot get the labor for repairs.

MR. NELSON. You are quite right. Manpower is the most critical material. But that is only another reason for the conservation program, because all the coal we use requires manpower, and all the transportation requires manpower, and the more we can cut down on wasteful uses, the more we will help out on the war effort.

MR. GORMAN. There is one other thing that I would like to say to you. The Water Division of OWU is seeking to represent our industry as effectively as it can under the restrictions that must be put on materials in order to win this war. But we need help. We need to have our fingers on the pulse of the water industry in various sections of the country. We are going to keep in touch with you through our regional engineers. If you think our policies are wrong in any case, please let us know, and we shall try to make changes which are equitable. Without the support that we have received from water utilities through the American Water Works Association, the New England Water Works Association, the Maine Water Utilities Association, and other associations, we would not be able to do this job effectively. We want to refer more of our problems back to the utilities themselves and get the benefit of their practical experience. It is not easy to get

*Auburn, Me.

people to come to Washington in these days because traveling is difficult; furthermore, it is hard to get reservations in hotels. But the mails are still operating, and whether you agree with us or not, we shall be pleased to get your viewpoint; and if we can get your viewpoint we shall be in a better position to serve you.

I particularly want to thank Harry Jordan for all the fine work he has done for us and for the water industry. Mr. Cook has represented your industry in this area on several of our committees. We are going to see that we have more industrial representation. Please do not feel hesitant in letting us know what your problems are. Mr. Snow will be in Washington, but he will be here a part of the time. He will, of course, work in harmony with our regional offices in New York and in Boston. The only decentralization that the Water Division is making at the present time is in connection with an office on the Pacific Coast. Gerald Arnold of the United States Public Health Service has been lent to us as the regional engineer for that area. He will review the projects on the coast and send them to Washington for priority allocation of materials and authority. Later there may be further decentralization, but at the present time everything will be handled in Washington with that one exception.

CHAIRMAN CLARK. The regional office here will not have the power to approve any application?

MR. GORMAN. The regional engineers will make recommendations. It is on the basis of their recommendation that priority and material allocation will be made.

MR. NELSON. Mr. Walters and Mr. Daniels are the officials in the Boston regional office of the War Production Board through whom you clear if you purchase more than $100 worth of any of the materials listed on Schedule C of U-1. They are also in a position and will be glad to help you locate other critical materials that you might not be able to get quickly delivered. They may be able to find them through the records of the War Production Board even if they are not on the special schedule.

ARTHUR L. SHAW.* I do not think we ought to let these gentle-

*Boston, Mass.

men go without expressing our appreciation of the change in the conditions in Washington, the more sympathetic attitude that the water works problems get there. Before Mr. Gorman took over, as you all know, it tooks weeks and sometimes months, and then it was necessary to get the support of your Congressman or your Senator in order to get much attention on applications for priorities. Since we have had a water works man and a water works organization that he has built up around him there I think that things have gone along tremendously more smoothly. There was one application in which I was interested just a week or so ago, which came back in exactly nine days from the day it was forwarded. That is just an example of what we get under this present setup, due to the fact that we have an understanding of water works problems there which we did not have before the Water Division was set up.

MR. NELSON. If you have a project in shape to be put in on WPB 2774, then apply for it in final shape, giving the quarter or quarters in which you want to do the construction. If it is not that far advanced but you are sure that you will want to go forward with the project, write a letter to Mr. Gorman and give him the information as to the approximate quantity and cost of materials involved so that he will be able to support the request which he makes to the Requirements Committee for allotment of material and equipment.

CHAIRMAN CLARK. That is for new construction?

MR. NELSON. For new construction.

LINN H. ENSLOW.* As I understand it, Mr. Gorman, the U-1 order has been changed in so far as the critical paragraph concerning the 1942 limit is concerned.

MR. GORMAN. That is right. Those utilities which had increased consumer demands and requested increases in inventory, withdrawals, and deliveries have been granted probational increases over their 1940 base. The P-46 inventory limitation was satisfactory to a very large percentage of the industry.

MR. ENSLOW. What do men do who feel the pinch?

*New York, N. Y

MR. GORMAN. There are always situations which make any overall ruling pinch. If it is pinching so that it is hurting service, please let us know and we shall try to do something about it.

MR. COOK. Can anything be said now on what we may expect on the $100 limitation on the materials in schedule "C"?

MR. NELSON. The Regional Utility people had a meeting a short time ago at which they discussed some possible changes in Schedule C of the Utilities Order U-1. There are possible changes in the lists under consideration, but whether they will change that amount or not, I do not know. They probably will take some items off the list so that you won't have to check them at all. But in any case, manufacture of material and equipment involves manpower, so that if you find from your Regional Utility engineer some place from which you can get material from existing stock, I know he will be glad to help you do so.

HYDRAULICS OF DISTRIBUTION SYSTEMS—SOME RECENT DEVELOPMENTS IN METHODS OF ANALYSIS

BY THOMAS R. CAMP*

[*Read September 29, 1943.*]

Since the introduction by H. L. Hazen and the author in 1934 of the electric analyzer method (1) of computing flow distributions in pipe networks, there has been a revival of interest in the hydraulics of distribution systems. The outstanding development during this period was the introduction in 1936 of the Hardy Cross method (2) of computing flow distributions. During the same period, the Freeman graphical method was expanded and developed by Howland (3) and Aldrich (4) to solve problems involving nets with cross-overs. All these methods may be described as trial-and-error procedures for estimating the distribution of flow and the head losses in water distribution systems under assumed conditions of inflow and draft. The Hardy Cross method, because it requires no apparatus and is faster than the other methods, has been quite useful for the design of small systems such as for military establishments; and has been widely acclaimed.

It has been pointed out recently by Gavett (5) that "The well deserved acclaim accorded this excellent method has given some writers, including editors, the misconception that, before the Hardy Cross method, it was not possible to design a distribution system and that pipe sizes were determined entirely by guesswork." Mr. Gavett is quite right in giving due credit to the older procedures which have been in use for many years. The contributions of Freeman and Allen Hazen were especially noteworthy, and many others have made valuable additions to methods of analysis of networks. There is, nevertheless, a reactionary note in Mr. Gavett's position which tends to imply that existing methods are good enough. A similar note is sounded in the comprehensive paper by Fair (6).

It seems pertinent therefore to point out at this time that all

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currently used methods of flow analysis, including the Hardy Cross method, are not adequate for the design of any except very simple systems. One has but to examine the literature to realize that the systems to which the Hardy Cross method has been applied involve fewer than about 100 loops. The populations involved are generally less than about 20,000. The method cannot be applied to a large municipality without drastically skeletonizing the system by omitting most of the smaller pipes.

In the design of a distribution system, or reinforcement thereto, the selected pipe sizes must be such as to deliver the required flow at the available pressure drop. This is only a part of the problem, however, since an infinite variety of sizes can be made to accomplish this function. It is surely of no less importance that the sizes should also be selected to make the total cost of the system a minimum.

It has been shown by the author (7) that the selection of economic pipe sizes requires a knowledge of the discharge and head loss for every pipe concerned for both the normal domestic flow and the peak fire flow. The process of determining the economic diameters is also trial-and-error as follows: (1) pipe sizes are assumed; (2) the hydraulic analysis is made for the double purpose of determining whether the allowable overall pressure drop has been met and of finding the discharge and head loss for each section of pipe; and (3) economic diameters are computed for each section of pipe. This sequence must be repeated until both pressure drop and economic requirements have been met.

There has been a notable lack of discussion of economic pipe sizes in the literature on the design of distribution systems during the past decade. This is understandable in view of the fact that we are not yet ready or able to do a real job on the selection of economic pipe sizes. The bottle neck is still the hydraulic analysis. To obtain the discharge and head in each section of pipe, more precision is required than is necessary to estimate the overall pressure drop. The tremendous amount of work which is required to obtain the results for a single hydraulic analysis, even for the simple systems that have so far yielded to the Hardy Cross method, tends to discourage attempts to find economic pipe sizes. When one considers the extension of these methods to large cities, the job seems wholly impractical.

Problems do arise in large cities, and most of the investment in distribution mains is in cities whose systems involve more than 100 loops. These problems have to be solved, and a number have been attacked by the Hardy Cross method (8). In order to do so, however, it has been necessary to omit from consideration most of the smaller pipes. This process of skeletonizing introduces errors in the results which are of unknown magnitude. It is general practice to skeletonize a system for the obvious reason that it must be done on large systems if any results at all are to be obtained by the methods now available. Nevertheless, there is no way of evaluating the errors introduced by this procedure except by solving for the flow distribution with all pipes considered.

Both Tyler (9) and Fair (6) imply that it is not necessary to apply the Hardy Cross method to a large network as a whole. According to Fair, "Much information can be obtained more quickly and more simply if the method is used to balance portions of the system in succession." Unfortunately, this is not the case. No part of a system can be isolated for analysis by the Hardy Cross method, or any other method, unless the discharge and pressure is known for every pipe at the boundary of the district so isolated. One may assume a division of the flow into the district among the pipes which cross the boundary, or one may assume the pressure at these points. Such assumptions, however, introduce an element of "guesswork," and the magnitude of the errors may be just as great as with the older methods that Mr. Gavett defends.

Most of the improvements to the Hardy Cross method have aimed at simplifications and the saving of time in its application. It seems evident that the Hardy Cross method, together with the trial-and-error electric analyzer and Freeman graphical methods, will always be limited in their application to very simple systems. Aside from the great amount of time required, there is another limiting factor which has not been given much publicity; namely, the fact that there is nothing embodied in the trial-and-error methods which insures convergence of the errors towards zero with repeated adjustments of discharge.

It is usually claimed that the Hardy Cross method will yield results of sufficient accuracy with three or four corrections to the dis-

charges, but this is not true for all systems. In about one-fourth of the loops in the Needham, Mass., system (Figure 1), which was studied by Hammond (10) under the author's direction, a sufficient convergence was not in sight after eight corrections. The Needham system serves a population of about 12,000. The system shown in Figure 1, which was modified from the actual system in an attempt at economic design, consists of 61 loops and 162 pipe elements including 6-, 8-, 10- and 12-inch pipe. It is obvious from the figure that this system cannot be skeletonized without seriously modifying the distribution of flow.

The hydraulic analysis of a distribution system usually consists of solving for the discharge and head loss in each pipe element for a given assumed condition of inflow and draft. For convenience the draft from the system is assumed to be concentrated at a number of junction points. For each pipe element there are two unknowns, the discharge and the head loss; and for the system as a whole one unknown, the head loss or discharge. Hence the number of unknowns equals twice the number of elements plus one.

The equations required for the solution of the unknowns are of three types and arise from three laws (11) as follows:

I. The head loss in each pipe is a function of the discharge. For convenience, an empirical exponential relation is assumed such that

$$h = k\,Q^{x} \tag{1}$$

II. The algebraic sum of teh rates of discharge towards any junction point is zero,

$$\sum Q = 0 \tag{2}$$

III. The algebraic sum of the head losses around any closed circuit is zero,

$$\sum h = 0 \tag{3}$$

For any network the number of equations available is sufficient for a solution. To solve for the unknowns, the equations must be solved simultaneously, but the direct solution of the large number of simultaneous equations involved in distribution systems is impractical for all but the simplest systems. For example, a loop with one cross-over

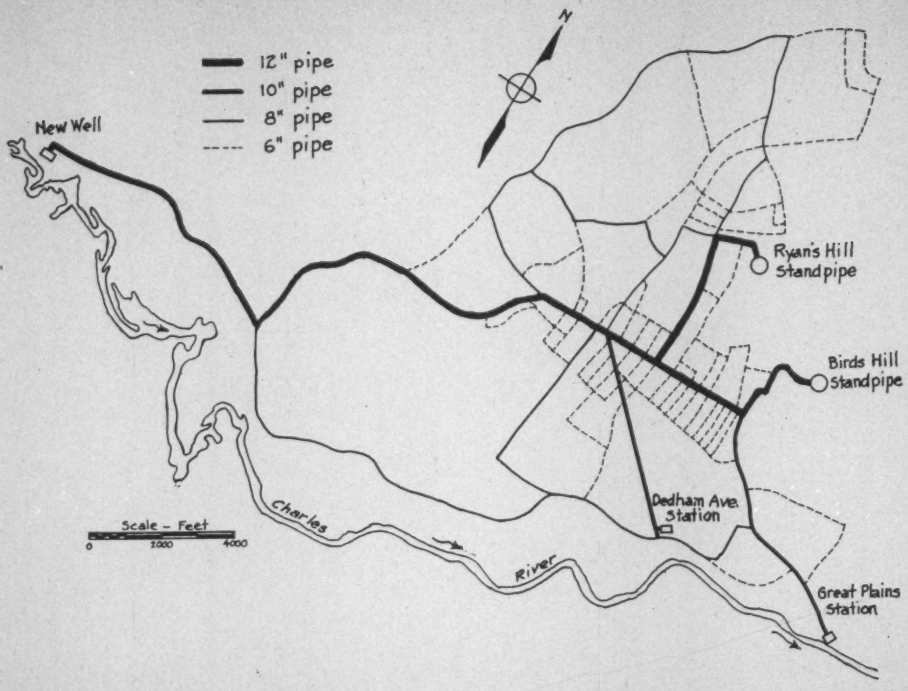

FIG. 1.—TRIAL SYSTEM FOR NEEDHAM, MASS.

requires 11 equations for solution. Hence trial-and-error methods are required in practice.

The Hardy Cross method as usually applied consists of: (1) the assumption of Q for each element to satisfy Equation 2 and the assumed loading condition; (2) the computation of h for each element from Equation 1; (3) the computation of the error in head loss around each loop from Equation 3; (4) the computation of a correction in discharge for each loop from Equations 1 and 3; and (5) the application of the correction to the discharge in each pipe. The sequence is repeated until the error becomes sufficiently small for the required accuracy.

The original electric network analyzer method consists of an electric model of the system in which each pipe element is represented by an adjustable electric resistor with linear voltage-current characteristics interconnected in proper position. Discharge is represented to convenient scale by direct current, and head loss by voltage drop. Equations 2 and 3 correspond, on the electric model, with Kirchoff's laws for electric cricuits as follows:

II. The algebraic sum of the currents towards any junction point is zero,

$$\sum I = 0 \tag{2a}$$

III. The algebraic sum of the voltage drops around any closed circuit is zero,

$$\sum V = 0 \tag{3a}$$

For a true electric model of the hydraulic system, it is also necessary that

I. The voltage drop in each electric element is a function of the current such that

$$V = KI^x \tag{1a}$$

Since from Ohm's law $V = RI$ for a resistor with linear voltage-current characteristics, where R is the electrical resistance in ohms, it is obvious that each resistor must be so adjusted that

$$R = KI^{x-1} \tag{4}$$

in order to meet the requirements of Equation 1a. Experience indicates that three or four traverses of the system are required to adjust

resistors to meet the demand of Equation 4; but, as with the Hardy Cross method, there is no assurance that a balance can be obtained for any system.

In the modified Freeman method, Equation 1 for each element is represented by a curve drawn on transparent paper or celluloid. The conditions of Equations 2 and 3 are met by shifting the proper curves on the drafting board until a balance is obtained.

The present indications are that hydraulic problems relating to distribution systems for large cities can be solved satisfactorily *only* by means of models. To be useful for this purpose, a model must truly represent the system so that pressure drops and discharges can be measured directly without trial-and-error procedures. Recent developments to be described presently indicate that both electric and hydraulic models can now be constructed to fulfill this requirement.

The immediate reaction to the use of a model for the design of reinforcements to a large system will be that the cost of the model is too great, particularly if the model must represent the whole system. This is undoubtedly true if the model is constructed only for a current problem. If, however, the model is built and staffed by the city and is kept up-to-date continuously as new results become available from flow tests and water waste surveys, it can be used on every problem involving extensions, reinforcements or replacements. It will probably pay for itself if a five per cent saving in cost of reinforcements is obtained. It is not too much to hope that much greater savings can be effected, since no adequate method for determining economic sizes has heretofore been available. It is worthy of note that many of the large distributors of electric power now have their own electric network analyzers for solving electric distribution problems.

Since 1934, studies have been in progress under the direction of H. L. Hazen of the Department of Electrical Engineering at the Massachusetts Institute of Technology which have had as their object the replacement of ordinary resistors in the electric network analyzer with resistance elements whose volt-ampere characteristics are similar to the head-discharge characteristics of pipes. It was found that the resistance of a number of filaments in commercial vacuum tubes increases automatically with increased flow of electricity (due to heating) in such a manner as to conform with Equation 4 over a limited

range of current and voltage. Any reasonable value of the exponent x between 1 and 2 can be satisfied by careful selection of tubes.

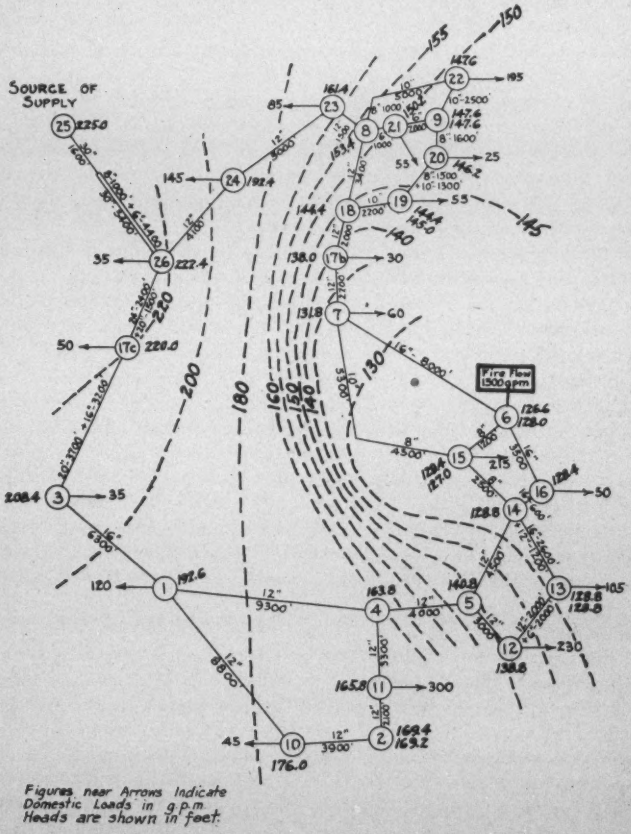

FIG. 2.—WATER DISTRIBUTION SYSTEM, WARWICK, R. I.
Pressure Gradients for Fire at Point 6. Solution by Electric Network Analyzer.

Strandrud (12) developed a method for designing tungsten filaments for use with a value of $x = 1.85$, satisfying the Williams and Hazen pipe-flow formula, over a limited current range. Laurent (13) found that several commercial vacuum tubes have current-voltage relations such that $x = 1.85$ over a fairly wide range of current. Cook (14) constructed an electric network analyzer using commercial radio tubes, and was successful in solving some simple network problems with direct readings of voltage and current. With the scale ratios selected by Cook, he found it necessary to use an average of 14 tubes per element properly to represent the hydraulic system.

In 1942, Quill (15) succeeded in representing the skeleton system for Warwick, Rhode Island, shown in Figure 2, with a vacuum tube network analyzer, using an average of only 3 tubes per element. This system was first solved by Collins and Jones(16) in 1933 using the electric network analyzer with adjustable resistors. The Collins and Jones solutions, one of which is illustrated in Figure 2, formed the basis of the original paper (1) on the analyzer by Hazen and the author. The same system was used by Doland (17) to introduce the Hardy Cross method in 1936, and again by Aldrich (4) for the Freeman graphical method in 1938. The same problem has now been solved by Quill with equal accuracy by means of the vacuum tube analyzer.

Quill's solution of the problem illustrated in Figure 2 is shown in Figure 3. There had been a small change in the distribution of domestic loads, but the pressure drops are practically the same as obtained by Collins and Jones. The vacuum tube analyzer used by Quill is shown in Figure 4. The take-off loads were composed of slide-wire resistors which were adjusted by hand, but studies indicated that constant current vacuum tubes could be used to represent the loads. The advantage of the vacuum tube analyzer is that, once the model is constructed, new loading conditions may be imposed or reinforcements introduced with great rapidity and the resulting distribution of current and voltage read immediately. Figure 5 shows the effect of a reinforcing main of 16-inch pipe 7500 ft. long between points 26 and 7, as solved by Quill.

Many problems relating to the use of vacuum tubes in models for large distribution systems will require careful study. Among these are the cost, the method of design, life of tubes and frequency of replace-

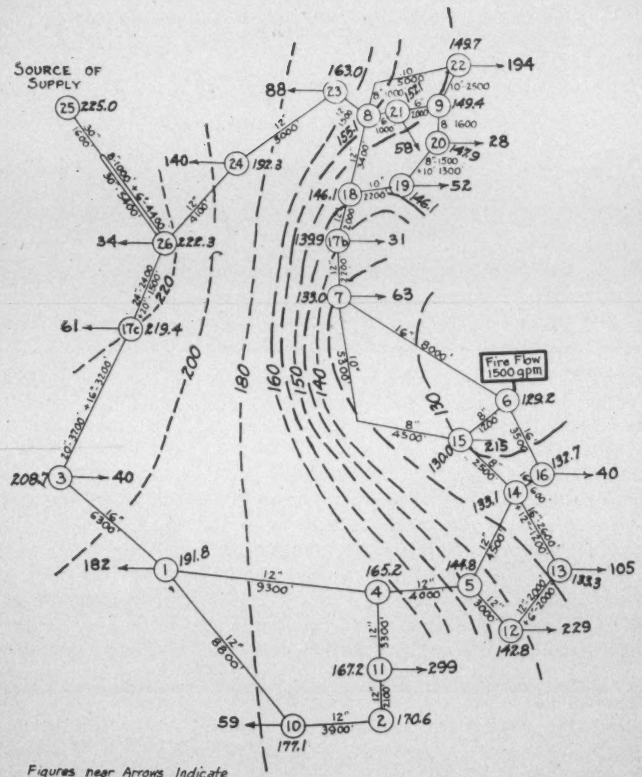

FIG. 3.—WATER DISTRIBUTION SYSTEM, WARWICK, R.I.
Pressure Gradients for Fire at Point 6. Solution by Vacuum Tube Analyzer.

ment, ventilation or cooling of the model, method of representing take-offs, the method of making studies, and the personnel required.

Quill (15) made experimental studies of the life of the filaments in

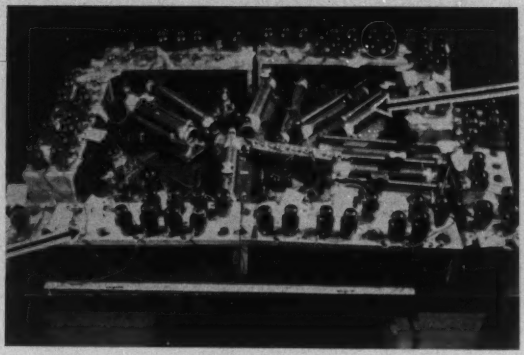

FIG. 4.—VACUUM TUBE ANALYZER FOR WARWICK SYSTEM.

two types of commercial vacuum tubes whose current-voltage characteristics were satisfactory for water distribution system models. Twelve tubes of each type were operated continuously at 10 volts for 2000 hours without failure. The tubes were rated at only 6.3 volts, but were tested at 10 volts because this was considered a probable maximum for the tube when used in the analyzer. Since further tests at higher voltages indicated that the life of the filaments was about inversely proportional to the 7.5 power of the voltage, it is probable that a life much in excess of 2000 hours can be had if the tubes are operated nearer their rated voltage.

Quill also found that the value of the exponent x in Equation 1a was not changed appreciably during the life tests, but that the coefficient K decreased about 15% after some 600 hours and thereafter remained constant. These tests seem to indicate that tubes should be subjected to an accelerated aging process before being used in the analyzer. Quill's work on tube life, however, was of a preliminary nature only, and much more extensive studies are required to obtain knowledge adequate for sound design.

The possibility of using small hydraulic models for studying distribution systems has long been considered. The principal stumbling block has been the difficulty of representing each pipe with a model

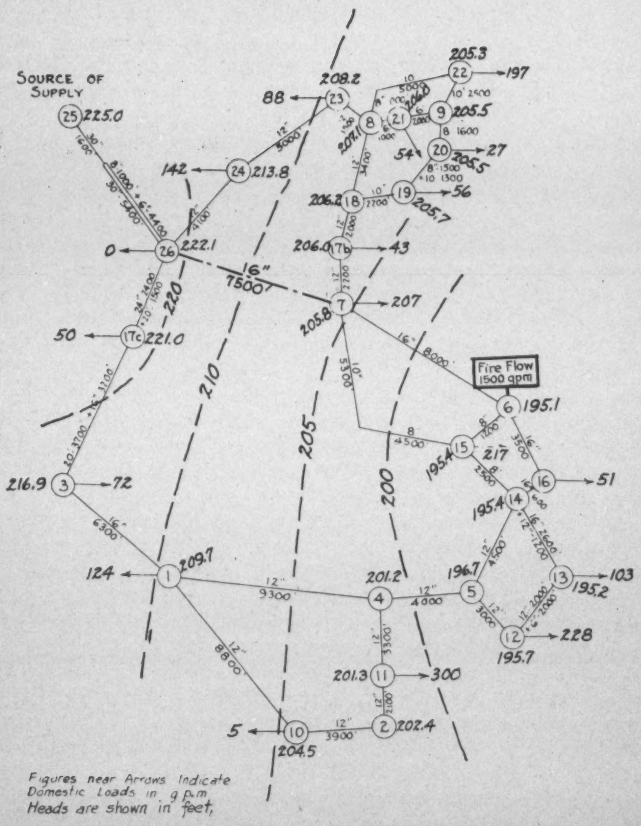

FIG. 5.—WATER DISTRIBUTION SYSTEM, WARWICK, R. I.
Pressure Gradients for Fire at Point 6. Showing Effect of 16" Reinforcing Main. Solution by Vacuum Tube Analyzer.

having the same hydraulic properties, such as are characterized by k and x in Equation 1. If a pipe or tube is used in the model to represent a prototype pipe, the model pipe must be fairly large to insure that the flow will be turbulent. The difficulty of reproducing Equation 1 with the proper value of the exponent x in such a model seems insurmountable.

Gavett(5) has overcome some of the difficulty by representing each prototype pipe by an orifice in the model. The orifices were drilled in copper discs which were inserted in rubber tubing connecting the junction points. The size of tubing and orifices must be such that nearly all the head loss is in the orifice jet. The principal objection to Gavett's method is that the exponent x in Equation 1 equals 2.0 for an orifice, which is too high for all but the most highly tuberculated pipes of a distribution system.

Thomas (18) has constructed hydraulic models in which the pipe elements are represented by constrictions in rubber tubes produced with pinch cocks. A pipe element is reproduced in the model by adjusting the pinch cock so that k in Equation 1 bears the proper scale ratio with the prototype. Discharge and head loss for each model element must be measured during the adjustment of the pinch cock.

According to Thomas, it is possible to obtain an average value of about 1.75 for the exponent x by judicious selection of size and thickness of rubber tubing. The value of x will also be influenced by the amount of throttling due to the pinch cock.

The constriction due to the pinch cock is analogous hydraulically to a short tube. The head loss is a combination of entrance loss, loss in the tube and exit loss. The entrance and exit losses are proportional to the square of the discharge ($x = 2.0$), but the loss in the tube is proportional to some power of the discharge between 1.0 and 2.0 depending upon the amount of turbulence present.

In order to fix the value of the exponent x to any desired value in a hydraulic model, it is evident that a pipe element may be represented by one or more short capillary tubes inserted in a larger tube of negligible head loss. The head loss through a short tube may be represented by

$$h = k_1 Q + k_2 Q^2 \qquad (5)$$

in which the first term on the right-hand side is the loss due to drag

in the capillary tube and the second term is the combined entrance and exit loss. Thus by changing the relative magnitudes of the first and second terms in Equation 5, which can be accomplished by varying the ratio of length to diameter, it should be possible to adjust the exponent x in Equation 1 to any value between 1 and 2 over a limited range of discharge.

With this object in view, a study of short capillary tubes was made by Davis (19) in the Sanitary Engineering Laboratory at the Massachusetts Institute of Technology under the direction of P. C. Stein and the author. The immediate purpose of the study by Davis was to find the dimensions of some tubes of small bore for which the $h - Q$ relation would be such that it could be represented by Equation 1 with a value of 1.85 for the exponent, and to determine the range of discharge over which the tube characteristics could be represented in this manner.

Davis used tubes of 1.98 mm. and 2.90 mm. diameter. The ratio $\frac{L}{D}$ of length to diameter ranged from 3.01 to 11.15, the length being that of the straight portion of the tube as shown in the sketch at the lower right of Figure 6. The tubes were drilled from brass rods, and an effort was made to round the entrance and exit to a radius of about $\frac{1}{4}$ D as shown. The rounded entrance was considered essential to permit reversal of flow through the tubes without change in entrance loss. Some of the results of Davis' experiments are shown by the curves of Figure 6. It will be noted that the value of the exponent x was reasonably constant when the Reynolds number $\mathbf{R}$ exceeded about 800, but below this value for $\mathbf{R}$ the characteristics were not dependable. The maximum value of $\mathbf{R}$ in the experiments was 7600, but there was no indication that higher values could not be used.

Davis' experiments seem to indicate that a value of $x = 1.85$ can be obtained in short tubes if $\frac{L}{D}$ is between 3 and 8 and the tubes are operated at Reynolds numbers between 800 and about 8000. The value of k in Equation 1 increases with the length, increases with decrease in diameter and is markedly affected by the entrance to the tube. Two of the smaller tubes used were identical except as to the amount of rounding at the entrance. The tube with the least rounding

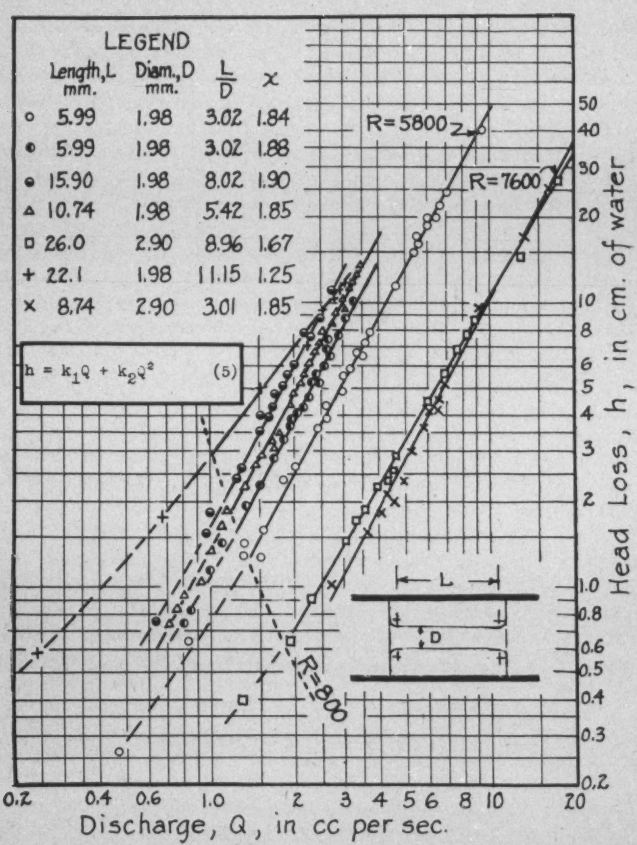

FIG. 6.—HYDRAULIC CHARACTERISTICS OF SHORT TUBES.

had a value of k about 50% higher than the k value for the other tube. These results indicate that high precision in machining or moulding will be required to produce tubes with the same characteristics.

In the experiments by Davis, the head loss by viscous drag in the tubes was about 1/3 the total head loss. This portion of the head loss is inversely proportional to the viscosity of the fluid used in the tests, and is thus influenced considerably by the temperature of the fluid. If water is used, at room temperature, a variation of 3°F. in temperature will introduce a 4% change in viscosity and a corresponding change in h of 1 to 2%. For this reason, a hydraulic model using short tubes, or pinch cocks as in Thomas' work, should be operated at constant temperature, with a variation of not more than about ±1°F. This will require accurate temperature control in the model room.

It is probable that one of the principal difficulties which will be encountered with large hydraulic models is that of maintaining constant characteristics for the elements. Dust, grease, and air in the model liquid will all change these characteristics; and corrosion, swelling or disintegration of the surface at the constrictions will have similar results. Much development work will be required before a satisfactory hydraulic model can be built for a large distribution system.

From the work thus far done on both electric and hydraulic models it seems clear that there are no insurmountable obstacles in the construction of individual elements to represent the pipes of a large water distribution system to true scale. The next step to be taken is therefore that of determining the nature and magnitude of the problems which will arise when these elements are incorporated into the complex model which will be required for accurate representation of a large water system. Numerous problems will appear in the construction and operation of a model containing perhaps 200 to 50,000 elements which will not arise with a small model containing 100 elements. However, the work done thus far on both the hydraulic and electric model schemes has yielded sufficiently encouraging results to justify the careful and extended additional studies that will be required to determine the practicability as contrasted with the possibility of building large and really useful models.

When one considers the rather large investments in water dis-

tribution systems, $10 to $60 per capita, and the not inconsiderable annual expenditures in replacements, extensions, and reinforcements to meet growth and new demands, it is apparent that if a model results in only a small percentage saving in annual costs a sizeable sum of money is justified for a model and model studies. For example, the investment in the distribution system for New York City is about $250,000,000. The annual cost of replacements and extensions is probably about 3% of this or $7,500,000. If by means of model studies a saving of only 5% can be attained, the justifiable annual cost of the model is $375,000. It is probable that model studies will not cost anything like this figure.

It is not impracticable to make studies now that would yield fairly conclusive data on the cost and feasibility of constructing and operating a model for a system as large as that of New York City requiring some 50,000 elements. However, a model comprising about 2000 elements applicable to a city of about 200,000 and involving a 30-fold extrapolation from studies thus far made would be equally useful and would be a more moderate next step to undertake. Most of the problems that would appear in the largest model should be encountered in this medium-sized model. The results obtained from the operation of a medium-sized model should make it possible to design a very large model with considerable accuracy and assurance.

All the foregoing arguments apply to both the hydraulic and electric schemes. The next work to be undertaken should unquestionably include both hydraulic and electric systems. A moderate amount of engineering time should develop whether either scheme has a conclusive advantage over the other and should produce definite plans and specifications for a model on one or both systems. It should also serve to indicate rather definitely the order of cost of obtaining results by model methods, and therefore should show the economic justification for building a model.

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Discussion

Chairman Clark. What would be the cost of a model for a town the size of Needham, say?

Professor Camp. The cost of the model itself is made up principally of whatever is used to represent the elements. In the case of an electric system, the cost would be in the vacuum tubes or other resistors and in the means for representing the junction points. It seems to me that the cost per element would be somewhere between $1 and probably $5 or $6, but reliable figures cannot be given until some actual cost studies are made. For instance, in the vacuum tube analyzer we have used rejects which are not satisfactory for commercial use. The rejects now cost nothing, but if we wanted them in lots of 50,000 they would probably acquire value very soon. The cost, however, is not solely the cost of obtaining the vacuum tubes. They must be calibrated, and that takes labor. We do not know yet whether we have to calibrate every individual tube or whether we can calibrate them in lots. In the hydraulic system the cost would be made up of the short tubes plus, again, the junction points. I think probably a judicious design of the junction points might possibly reduce the cost of those down to 60 cents to a dollar. The cost of the short tube would probably be much less than that. But estimating the cost is not the whole problem. It is possible that the hydraulic model may not work satisfactorily due to such difficulties as keeping air out, and similar difficulties may develop with electric models. These are problems which will have to be studied on a much larger scale than has so far been the case.

Harold W. Griswold.* Would it be all right to chamfer the ends of the tubes instead of giving a rounded entrance?

*Hartford, Conn.

PROFESSOR CAMP. It will be necessary to round the entrance because the chamfered entrance will introduce separation at the walls with eddies and entrance loss of unpredictable magnitude. Hence, every effort should be made to eliminate the entrance loss altogether by rounding the entrance. I rather suspect that these capillary tubes can be most economically made by molding them from plastics.

WILLIAM W. BRUSH. You spoke about large systems and the analysis of such systems. Just how would you take care of the changes in the loss of head in the different parts of the pipe system? Presumably, the pipe coefficients would change with age and they would have different values in different parts of the system. Today a single water system may have some cast-iron pipe with cement lining for which there is only a slight change in the Hazen and Williams coefficient C. The same system may leave older pipes with coefficients as low as 20, and some pipes whose coefficients will come in between, representing the greater part of the system. Would you propose to handle the changes that would take place by attempting to lay out very closely the increases in trunk main capacity, which I understand to be the objective, so as to come within the errors that you have indicated in your talk?

PROFESSOR CAMP. At the start undoubtedly there would be very large guesses, but all the data collected from hydrant tests and water waste surveys should be made available to the persons operating the model. It would naturally be a job for the operating staff to try to keep the model up to date. It might be that you could really represent the system with comparative accuracy. However, the problem which would arise would arise in some particular parts of the system requiring reinforcement. Hydrant tests would have to be made for that particular part of the model, and coefficients could thus be made available which are much more accurate than for the rest of the system. The big pressure drops would occur in the region under study and I think a high degree of precision could thus be had for any particular reinforcing problem.

EDWIN B. COBB.* In the case of your study in Needham, how

*Boston, Mass.

many trials were made to make that system close? Did you just start off with the assumption and then go through eight times to see if you could get the right answer, or did you try again after two or three trials with new flows? We have found a good many times that if you do not start off right you never get the answer. If, however, after a couple of trials you start over again, you could then get the system to work out and get a satisfactory answer.

PROFESSOR CAMP. The Needham study was made by Leroy Hammond, a student. He made eight traverses of the distribution system and about 30 per cent of the loops did not close satisfactorily. Later we set the problem up and made a separate determination of flow distribution, different from the original. After the fourth correction we found the same loops were still failing to conform. The point I wish to make is that any trial and error method, even if it does close is going to be unsatisfactory for a big system because it takes far too much time.

GORDON M. FAIR.* The writer has a good deal of sympathy for the author's counsel of perfection. He cannot help feeling, however, that in his search for the perfect procedure of network analysis, which is pointed towards the creation of a suitable model, or laboratory instrument, the author appears to brush aside, by implication, all office procedures such as the Hardy Cross method, which by themselves or in combination with field tests offer a fast, reliable, and economic solution of most network problems. This "reactionary note" in the writer's position is justified by the fact that, in normal engineering experience, no pipe network of appreciable size is ever built from the ground up. The problems to be solved are connected with the strengthening of existing systems, or with their extension. Many parts of the system, therefore, are affected only indirectly, if at all, by the proposed changes. These parts can be isolated for analysis by field and office procedure, because discharge and pressure can be determined for every pipe at the boundary of the district that is isolated. In other words, much of the system can be investigated in the field to obtain answers that the author would try to obtain from a model. The writer hesitates to suggest how much good and

*Cambridge, Mass.

valid work can be done by a squad of engineers and their assistants operating on the additional engineering budget of 5% of the cost of construction proposed by the author. On the whole, it would appear that an equivalent amount of money invested in mainline meters and gages, and in engineering personnel would be of greater benefit in the intelligent and economical development of a distribution system than the construction and operation of a model. For it must be remembered that the model is based upon constants, the hydraulic equivalent of which must be obtained by flow tests in the field, and that the rate of obsolescence of mechanical, and especially electrical devices is rapid.

HAROLD A. THOMAS, JR.* William James has said, "The intellectual life of a man consists almost wholly in his substitution of a conceptual order for the preceptual order in which his experience originally comes." The main effort of the thinker is to translate his experiences into the realm of thought in which *ideas* replace *things*. Such substitution constitutes the basis of the scientific method. The more complicated the empirical order, the greater the need of conceptualization. Certainly the problem with which Professor Camp has concerned himself is complicated, and there can be no doubt but that he has been eminently successful in its conceptualization. This most recent paper of a group dealing with the hydraulics of distribution systems gives added indication of the author's originality and penetration of vision.

The remarks concerning the limitations of the Hardy Cross method merit special emphasis. This method is a special application of the general technique of relaxation used in other branches of engineering. Common experience has been that while often extremely useful, no universally applicable means exist to set up problems so as to insure convergence of successive approximations. A casual understanding of the method based upon the successful solution of a few systems is misleading. It is possible to solve perhaps a dozen systems by the Cross Method before encountering one that poses special difficulty in the matter of convergence. A considerable amount of theoretical work could be done before the method assumes its rightful place as a valued tool in the kit of the engineer.

*Cambridge, Mass.

Professor Camp has made a valuable contribution in bringing out the utility of models, both hydraulic and electric, in the analysis of large distribution systems. Such systems can be treated with the Cross method only with an almost prohibitive amount of numerical work. While not disagreeing in principle with any of Professor Camp's tenets, it would appear to be very much to the point in a discussion of his paper to examine a cogent limitation inherent in all practical hydraulic network analysis. This limitation stems in part from incomplete observational information and in part from the initial condition that in analysis we have necessarily substituted *concepts* for *facts*. The difficulty is basic, though strangely enough, it is seldom mentioned. Probably this is because the resolution of the problem presented is very considerably more complicated than the forthright hydraulic analysis usually undertaken.

Ordinarily, if the distribution system under analysis is small or of moderate size, and a reasonable amount of field testing has been done, the hydraulic analysis may be undertaken with the expectation that the results will be significant. Sometimes, however, this is not the case. It can be shown that in occasional problems, even where the number of pipes is small, the necessary precision cannot be attained without a very considerable amount of field data. If the distribution systems are large, involving hundreds and thousands of elements, the analysis of which is envisaged by Professor Camp, then the question of precision may well become paramount. Experience in analysis of a number of systems for the Army and others by means of hydraulic models have led to the conviction that when a system involves more than a hundred (say) elements, then the significance of the results is likely to be materially limited by incomplete data even though two or three times the usual amount of field work has been done. It is of interest then to turn a critical searchlight upon the interrelation existing between the precision of available information of pipes and the precision of the analytical result. How much field data must be obtained before it is permissible to attempt an office study? Due to the complexity and pitfalls in the way of lucid thinking, it is well to commence with the first step in the accepted process of conceptualization.

What is the nature of knowledge of a pipe line that has been

under the ground a number of years? It is readily seen that such knowledge, if any, must be one of two sorts: (a) direct observational knowledge obtained by field tests, (b) indirect knowledge acquired by experience with other pipes in the system, or pipes in similar systems. Obviously, the first type of knowledge is more accurate and hence, more useful; unfortunately, field tests are expensive and it is not often feasible to test every pipe. Indeed, if every pipe were to be tested, it might well be possible to arrange the field work so as to eliminate completely the necessity for numerical or model analysis of any sort.

However, at best, field tests supply only imperfect knowledge even for the pipes directly concerned. Precision obtained in field measurements is of a low order, as anyone is aware who has had the task of interpreting an extensive series of such measurements. Moreover, the observations vary with such factors as time and temperature, so that as the years go by and the seasons change, at no time is a perfect knowledge of the condition of the pipe available. Therefore, *the analyst must inevitably deal with imperfect knowledge.* It is instructive to examine the nature of the consequences as the analysis proceeds.

The next step is to incorporate the imperfect data into an imperfect formula, such as the Williams-Hazen formula, which expresses a relationship between head, pipe characteristic, and flow. Other somewhat more precise formulations exist in the wake of the westward sweep of fluid mechanics during the past two decades. These in general are more complex and less wieldy than formulas of the simple exponential type such as that of Williams and Hazen. However, all formulas are idealizations and are incapable of a perfect representation of the response of a pipe to a pressure gradient.

Ordinarily, however, errors introduced by inadequacies of formulation are obscured by incompleteness and unreliability of data. In fact, it is customary to throw all uncertainties, discrepancies, and residuals of error due to both formulation and data into a single factor, the roughness coefficient which, if the Williams-Hazen formula is employed, is reflected in the much abused factor C.

The foregoing considerations relate to the *causes* of error in the roughness coefficient; it is informative to consider the *nature* of such

error. It is well known that errors are of two sorts, compensating and non-compensating. Compensating errors are ones the average of which *taken for a large number of trials* approaches zero. If field tests are unavailable, experience has shown that errors the analyst is likely to make in elimination of roughness of a system of pipes will be non-compensating. That is, he is likely to assume values that are either too high or too low on the average. Large errors of this type are possible. It is a matter of common knowledge that the water of different communities has markedly different propensities to corrode, or to encrust. Various tabulations showing the decrease of capacity with time indicate variations as great as two or three hundred percent. If tabulations obtained for one situation are used to estimate the roughness coefficient in another, it is possible to introduce an amount of error such as to render the results of the computation completely meaningless. An appalling amount of time has been wasted in this manner. Analyses by the Cross method have been published for systems involving scores of pipes whose roughness has been estimated from little or no observational information. Regardless of the method of analysis, whether analytical or model, the results are no more significant than the data embodied in the solution.

Now consider the case in which the presumption is tenable that the errors are of a compensating nature. The average of the errors made with the assignment of a particular value of C to each pipe may be taken as zero or nearly so, providing the number of pipes averaged is very large. This emphatically does not mean, as some have supposed, that the error of the result will be zero or nearly so. It will be shown that in certain types of problems that the error in the result, despite the tendency of the errors to compensate each other, definitely limits the value of the analysis.

Unless extensive field tests are available, the errors which are inevitable, are very likely of the non-compensating type. It is in the nature of things that the least serious error that can be made is of the compensating type. Therefore, in order to view the feasibility of analysis of large systems in as favorable light as possible, it is necessary to investigate the consequences following the introduction of compensating errors into the analysis.

A simple analogy may lend insight into the nature of compen-

sating errors. Suppose a coin is tossed 1000 times and the result, head or tail, noted after each trial. Common experience will lead us to suppose that the number of heads will be in the vicinity of 500. Assume for the purposes of illustration that heads appeared 480 times. This would constitute a deficiency of 20 below the expected average value of 500. The proportion of heads would be 0.480, a little less than the value of ½ that experience has indicated will be approached in a very large number of trials. Now the important point, which is derived both from experience and the theory of probability, is the following: The *proportion* of heads will tend to approach ½ with a discrepancy that varies inversely as the square root of number of trials. The most significant corollary of this fundamental truth is that the deficiency (or excess) will tend to become larger in direct proportion to the square root of the number of trials. That is, in 100,000 tosses we would be very much surprised to have a proportion as low as 0.480; in fact this result would constitute an overwhelming proof that the coin was not symmetrical. But on the other hand, we should reasonably expect, and more often than not would obtain, a much larger deficiency than 20. An ever increasing deficiency (or excess) is compatible with the idea of a proportion that approaches a constant. In the theory of measurements, as will be shown, an analogous concept holds.

In order to apply statistical theory to the hydraulics of distribution systems, it will suffice to commence with the simplest case, namely, several pipe elements connected in series to form a pipe line. The head, h, lost in each element as the result of the passage of a flow, Q, is conceived as being given by a formula of the type $h = kQ^{1.85}$, where k is the resistance of the pipe, compounded from its length, diameter, and roughness. Thus for n elements the overall head lost in the line will be:

$$h = (\Sigma k)Q^{1.85} = KQ^{1.85} \qquad (5)$$

where $\Sigma k = k_1 + k_2 + \cdots + k_n = K$, the equivalent resistance of the line. The problem may now be formulated as follows: What will be the difference between the actual head loss and the head loss computed from equation (5) due to compensating errors in each assigned value of the resistance, k. That is, given the proba-

ble error in each resistance, what is the probable error in h? The relation including errors may be expressed mathematically as follows:

$$h + E_h = (K + E_K)Q^{1.85} \qquad (6)$$

where E_h = probable error in h

E_K = probable error in K

Subtracting equation (5) from equation (6):

$$E_h = E_K Q^{1.85} \qquad (7)$$

Now if $K = k_1 + k_2 + \cdots + k_n$, then the probable error in K as the result of probable errors, $e_1, e_2, \cdots e_n$, in each k* is given by the following formula, which is derived in any modern treatise of the theory of probability:

$$E_K^2 = e_1^2 + e_2^2 + \cdots e_n^2 \qquad (7)$$

Hence by substitution of known (or estimated) values of errors, e, for the element resistances, the error in the equivalent resistance, E_K, may be found. Finally by substitution in equation (6) the error, E_h, may be evaluated and the problem solved.

A useful simplification results if we make the not unreasonable assumption that (in absence of other information) the errors, e, in the resistances are all equal. Equation (8) would then be written:

$$E = \sqrt{n}\, e \qquad (8a)$$

Therefore, dividing equation (6) by equation (4), the following simple proportion is obtained:

$$\frac{E_h}{h} = \frac{E_K}{K} = \frac{\sqrt{ne}}{nk} = \frac{e}{\sqrt{nk}} \qquad (9)$$

Equation (9) states that the relative error in the head equals the relative error in the resistance *divided by the square root of the number of elements*. The analogy with the coin tossing is immediately evident. The relative (or percentage) error in head loss *does decrease* as the number of elements are increased. This has lulled some into the supposition that the larger the system the less important are errors in resistance of each pipe. On the contrary, notwithstanding the *decrease* in the relative error, the actual error, E_h *tends to increase* as the number of elements is augmented. This is readily seen in the

*It is not difficult to show that in the Williams and Hazen formulation the percent (or relative) error in the resistance $100\, e/k$, is about twice (1.85), the percent error in the coefficient C. Thus, an error of 10 in a value of C of 100 for a pipe would occasion an error of about $0.2k$ in its resistance k. It is assumed that no error exists in nominal values of diameter and length.

case where all elements have the same resistance, k; if h in equation (9) be replaced by $n\ k\ Q^{1.85}$, the value of E_h will be given by

$$E_h = \frac{n\ k\ Q^{1.85}\ e}{\sqrt{n}\ k} = \sqrt{n}\ e\ Q^{1.85} \qquad (10)$$

The important result here is that as the number of elements is increased, the actual error in the head loss becomes greater. In many instances it is the actual error and not the relative error in the head loss that counts. Slight comfort it is at the time of a large conflagration to know that the percent error made in calculations of the slope of the hydraulic grade line is small, if the actual error is such that a negative pressure exists at a hydrant computed to be safe.

Clearly then, it is not the sole duty of the analyst to estimate the head losses and flow distribution; it may be equally important to form some notion as to the reliability of the estimate. In order to do this it is enlightening to state the foregoing problem in a different form as follows: Given the permissible limits of precision for the over-all pressure drop through n pipe in series such that it can be reasonably certain that sufficient residual pressure exists at the critical hydrant, how accurately must the Williams and Hazen coefficient for each pipe be known? The solution of this problem in this form is readily accomplished with the aid of equations (4), (6), and (7). Often it will be found that the requisite accuracy is of a surprisingly high order—higher indeed than ordinarily obtained.

Having considered the case of pipe elements in series, it is logical to inquire into the effect of compensating error upon the analytical result when the system has other configurations of pipes. As has been pointed out by Professor Camp, the ordinary algebraic analysis for all but the simplest systems is extremely complicated. The analysis of error of a system is many times more complicated than the analysis of flow distribution. Despite the complexity, it seemed worthwhile to investigate some of the common configurations involving pipes in parallel and series, single, double, and triple cross-overs in the hope of finding a basis for generalization. The results have been unanimous on one point, namely, that the absolute errors increase with the number of elements, other factors remaining the same. The conclu-

sion has a significant bearing upon the feasibility of analysis of large systems.

General theorems in electric circuit theory exist that are in line with this conclusion. Unfortunately these are not directly applicable due to the linearity existing between current and voltage (Ohm's law). While it is possible to make some generalizations applicable to non-linear systems, it is felt that the following analysis will be more satisfying and conclusive than abstruse algebraic theorems.

Represented in Figure 7 is a hydraulic network similar to that

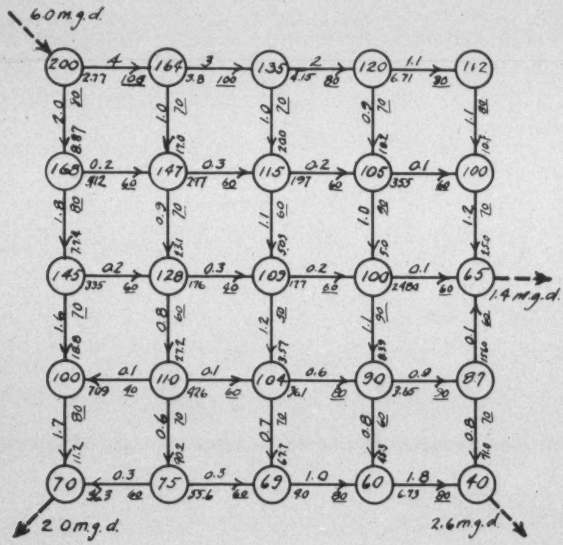

FIG. 7.

studied for a large factory engaged in the war effort. Because of wartime restrictions it has been necessary to alter the data relating to the actual configuration from those originally studied and reproduced to scale on a hydraulic model. The condition depicted is with three fires

at widely separated points such as might occur in a heavy aerial raid. The inlet at the upper left-hand corner is supplied from an emergency reservoir at a pressure of 200-ft of water when the necessary discharge is flowing. The hydraulic problem consisted of the estimation of head loss through the system. The value of the property was so high that it was considered worthwhile to form some idea as to the reliability of the estimate of head loss.

Figure 7 indicates the distribution of flow and the corresponding head (in ft. of water) at each junction (shown in circle), together with the assigned value of C (underlined) and the corresponding value of resistance, k, for each pipe. These assigned values of C were based upon a not inconsiderable number of field tests. Since it may be assumed that no error exists in given values of diameter and length of each element, the value of the resistance was readily obtained from the relation:

$$k = \frac{10.6\, L}{d^{4.87}\, C^{1.85}} \tag{11}$$

where L = length of pipe in feet
d = diameter of pipe in feet

On the basis of these "best estimates" of the resistance, the system was balanced with results shown in Figure 7. The over-all drop was 160 ft., leaving a residual pressure at the critical junction of 40 ft. This was deemed to be safe, provided the estimate could be considered reliable.

The next problem was to find an approach that could yield an idea of the reliability of the foregoing estimate. An exact algebraic analysis with a system of this size is practically impossible, indeed, even the solution by the Cross method requires an amount of time measurable in hours rather than minutes. One approach that is by no means irrational is to assume the entire hydraulic water table be tilted by an amount just sufficient to lower the pressure at the critical hydrant to a value of say 15 ft., which was considered to be dangerously low; *i.e.* assume that the hydraulic slope in each pipe is increased by a factor of (200-15) ÷ (200-40). This increase in slope could be realized by a constant relative decrease in the value of C for each pipe to about 92% of its original value. That is, if all the values

of C had been 8% lower, the analysis would have indicated that the system was not adequate. Since the average value of C was between 60 and 70 in the system shown in Figure 7, this approach in effect states that it is necessary to know the value of the roughness coefficient of every pipe to within about 5 units in order that the result be significant. This is a rigorous requirement.

However, there are objections to this method of error analysis. Chief among these is the assumption that the errors are all in one direction. Of course such non-compensating errors are possible, but they are not probable. The approach finally adopted presumed compensating errors and provided a satisfactory estimate of reliability. Unfortunately, it involves an almost Herculean amount of numerical work and consequently cannot be generally recommended. The labor having been accomplished in the study at hand, it stands as an excellent illustration of the nature of compensating error.

The essence of the method consists in replacing the original set of roughness coefficients with an "equally likely" set. The sense in which the words "equally likely" is used requires some elaboration. The original set of values were established by a capable group of engineers in applying their knowledge and experience to the interpretation of a record of field tests. Now assume that a second set of field tests was made with the same degree of completeness. The data obtained would of course be similar to, but not identical with the original. Next, turn the new data over to a different, but equally capable set of engineers for calculation of roughness coefficients. It is manifest that the new set will in general differ from the first, but since it had a similar genesis, it must be considered an equally likely set, subject to errors of the same order of magnitude as the original. Obviously, it would be inordinately expensive to proceed in this way. However, for the purposes desired, it was satisfactory to obtain additional equally likely sets of roughness coefficients in a simpler way.

A large number of paper slips that had been marked with various deviations (errors) in C were placed in a hat. The number of slips corresponding to each magnitude of deviation was made to correspond to the frequency given by the normal curve of error. In the system studied, a thousand slips were used, half of which had deviations less than 10, corresponding to the assumption made that values of C orig-

inally assigned were subject to a probable error of 10. This presumed that 50% of the time the originally assigned values were correct to within plus or minus 10. An equal number (500) of positive and negative slips was used. Therefore, the average value of deviations selected at random from the hat (each slip being returned prior to next drawing) would tend to approach zero as the number of drawings was increased. In order to obtain a new set of roughness coefficients, a separate drawing of a deviation was made for each pipe in the system. The deviations were used in computing new roughness coefficients. Such a set of coefficients is shown in Figure 8. For example, the pipe in the upper left-hand corner which originally had a coefficient of 100 (Fig. 7), acquired a deviation of minus 6 in the new drawing; hence the new value of C for that pipe is 94, as shown in Figure 8.

Having thus obtained a new randomized set of C values, the sys-

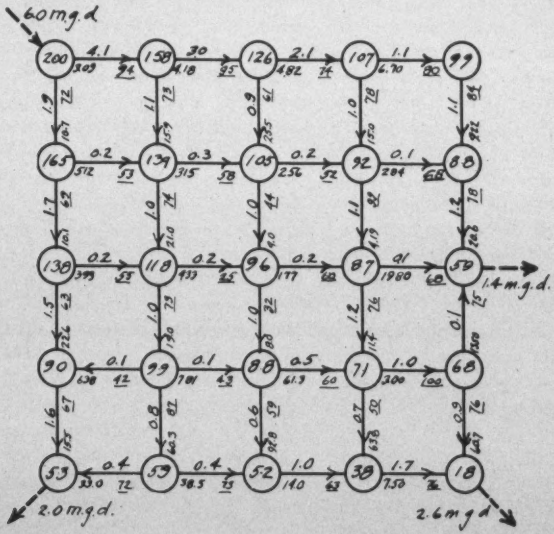

FIG. 8.

tem was again balanced and the over-all pressure loss evaluated. With the data of Figure 8, the residual pressure was 18 ft. instead of 40 ft. This is an "error" of 55% the original and moreover indicates a pressure that is dangerously low. The interpretation of this "error" was that in view of recognized uncertainties in C values, it was quite possible that the system was not adequate as originally believed.

The magnitude of the over-all error in pressure drop is determined not only upon the total amount of field testing but also upon the location of the stations at which measurements are made. If a system is so constituted so as to have one or two well defined critical zones, and most of the testing is directed toward the measurement of gradients between these and the incoming supply lines on the periphery of the network, then it is possible to compute average C values for the intervening pipes with but small errors. The over-all resistance must be distributed in a somewhat arbitrary manner among the various pipes concerned, but since the average value is rather precisely known, the computed total pressure drop cannot be greatly in error. If, however, it is desired to calculate the gradient in any direction other than those tested in the field, then the cumulative effect of individual errors in each element may be very large. Probable errors may be assigned to C values as determined by the usual method of testing a few critical gradients. These probable errors are anisotropic in their cumulative effects; the reliability of the over-all result depends upon the general direction of the gradient under consideration with relation to those studied on the field. In many cases it may be desirable to investigate a variety of critical situations. For example, in the analysis of a system for adequacy in event of aerial bombardment, there are many possible patterns of fires and mainbreaks, and the critical gradient may occur in a direction entirely different from those tested. It is a matter of considerable importance before making an extensive analysis or model study of a distribtution system to consider the relationships existing between (1) the amount and type of field tests that have been made and those that will be necessary, (2) the precision with which the resistance of the elements may be determined from field data, and (3) the cumulative effect of errors upon the significance of the results desired.

Further information regarding the reliability of the original esti-

mate was obtained by repeating the process of randomization and balancing. Four subsequent trials yielded the following series of values of residual pressure (in feet) at the low point: 36; 14; 58; 65. These, of course, were insufficient to establish completely the variation possible, but they clearly indicate that large deviations from the original value of 40 are readily obtained. Accordingly, it was judged that only a limited significance could be placed in the original result until a very considerable amount of additional field data was accumulated.

The purpose has not been to deny the feasibility of the solution of hydraulic network problems when pipe characteristics are not precisely determined, but rather to emphasize the rôle of precision and its influence upon the over-all result, particularly when the number of elements is large. While the methods presented for estimating the error are not refined, it is not often necessary to evaluate the error meticulously. It is much more rational to form some sort of an estimate of the error than to neglect the question of precision entirely.

In large distribution systems the cumulative effect of errors, even though they tend to compensate, may become so large as to limit seriously the value of the result. Unless a rather detailed analysis of error is made, moreover, the seriousness of the limitation is unknown. It is interesting to note that this is precisely what Professor Camp has said pertains to the result when the original system has been skeletonized. The method of skeletonizing has, however, at least the virtue of being less laborious. Consequently, it would appear that skeletonizing may be definitely indicated, in place of the inclusion in the analysis of a series of high resistance pipes whose effect on the magnitude of the result is likely to be counterbalanced by concomitant decrease in precision.

From the foregoing, it is manifest that a model of a large distribution system to be of value must be in close accord with the prototype it represents. The necessary degree of similitude cannot be based on a few tests; rather, as Professor Camp has said, the calibration may extend over a period of years in which the model is progressively corrected as field data accumulate. In this sequence of adjustment, account must be taken of the incessant effects of corrosion and other changes that occur. There is no doubt that satisfactory similitude can be obtained in this manner after a somewhat indefinite

period of time. The practicability of models cannot be fairly established until the amount of work and expense involved in reaching and maintaining the required degree of similitude is clearly realized. By means of error analysis along the lines described it is possible to estimate in any particular situation what order of similitude must be obtained between model and prototype. A preliminary investigation of this sort is helpful in deciding whether a model would be worth the investment.

PROCEEDINGS

SIXTY-SECOND ANNUAL CONVENTION
BOSTON, MASS.

September 28 and 29, 1943

The following synopsis of the proceedings of the Sixty-second Annual Convention is printed for the record.

The Convention was held at the Hotel Statler in Boston, Mass., and was confined to a two-day session because of the war.

TUESDAY, SEPTEMBER 28

Morning Session

Vice-President (Acting President) Horace L. Clark in the Chair.

The Annual Reports of the Secretary, Treasurer, Editor, Finance Committee, Library Committee, and Committee on Reciprocal Relations with the Institution of Water Engineers of England were presented, accepted, and ordered placed on file.

The Report of the Committee on Committees was referred to the Executive Committee for further study.

The following reports of Technical Committees were presented and accepted: Committee on Pressure Piping; Legislative Committee; and Committee on Water Works Coöperation in Defense.

Informal reports were presented also by the Committee on Cast Iron Pipe and Special Castings and by the Committee on Wartime Information. All formal reports are printed in this issue of the JOURNAL.

GEORGE A. SAMPSON. Specifications for Elevated Steel Water Tanks, Standpipes, and Reservoirs were prepared by the Joint Committee of the American Water Works Association and the American Welding Society. They were adopted by the American Water Works Association on June 26, 1941, and by the American Welding Society on July 23, 1941. They were then printed in the JOURNAL of the New England Water Works Association for December, 1941, and adopted

by the New England Water Works Association on September 15, 1942. Certain revisions have been prepared by the American Water Works Association. Those revisions were approved by the Board of Directors of the American Water Works Association on October 1, 1942. These revisions were printed in the JOURNAL of the New England Water Works Association for December, 1942. They have to do with clearing up certain ambiguities in wording, and in bringing up to the present time the welding practices by the American Welding Association, and some other minor details. In order that our specifications may conform with those of the American Water Works Association and of the American Welding Society, I move that these revisions as printed in the December, 1942, JOURNAL be approved by the New England Water Works Association.

The motion was duly seconded and carried.

CLOSING OF POLLS AND APPOINTMENT OF TELLERS

The Acting President declared the polls closed and appointed George G. Bean, George E. Mann, and Theodore L. Cate to count the ballots and report their findings to the Association on the morrow.

Luncheon Session

AWARD OF THE DEXTER BRACKETT MEMORIAL MEDAL

GORDON M. FAIR. Mr. President, honored guests, members of the New England Water Works Association, ladies and gentlemen: The water works engineer meets his obligations to society by building great and useful structures that gather, conduct, purify, and distribute water to the thirsty multitudes. So stoutly does he build that he may well sing with Horace:

"Exegi monumentum aere perennius regalique situ pyramidum altius, quod non imber edax, non Aquilo impotens possit diruere aut innumerabilis annorum series et fugat temporum."

"I have raised up a monument more enduring than brass and loftier in majesty than the pyramids, which neither gnawing rains nor furious winds, nor the endless procession of years, nor the march of time, can destroy."

The life of water works structures is almost without measure.

Among the monuments of antiquity they stand forth in grandeur, often still serving to this day the purposes for which they were conceived.

The water works of our own civilization are young. We know next to nothing about the span of their useful life. Yet we must know their probable age if we are to design our works intelligently and with economy. When one of us applies himself to the task of divining the probable age of water works structures by mathematical methods, therefore, he performs a service of rational prophecy that merits the recognition of his associates.

Small wonder then that your Committee under the chairmanship of Caleb Mills Saville—himself three times the medalist of this Association—has voted unanimously, and in spite of close competition by other excellent papers, to recommend to the Executive Committee of the New England Water Works Association that the Dexter Brackett Memorial Medal for 1942 be awarded to Arthur V. Ruggles for his paper "Determination by Statistical Methods of the Average Service Life of 6-inch Cast-iron Water Mains in Brooklyn New York," which was printed in the September 1942 issue of the JOURNAL on pages 361 to 389. Mr. Ruggles, it gives me great pleasure on behalf of the New England Water Works Association and as the representative of Messrs. Saville and Anthony to present you with the Dexter Brackett Memorial Medal.

ARTHUR V. RUGGLES. Professor Fair, President, Clark, ladies and gentlemen: It is an added honor to me to receive this medal from the hands of Professor Fair, so distinguished a leader in water works matters and such an indefatigable contributor to our water works periodicals.

I am very proud to receive this award from the New England Water Works Association, an organization for which I have always held the very highest regard, whose praises I have heard sung, and justly so, many times and in many parts of our country for its worthy contributions to water works knowledge, business, and ethics, and for the ideas and ideals which it has set forth and then helped to establish.

I am also glad that my paper, which had to do with problems of water works distribution, a field which was the special concern of

Dexter Brackett,—to whom we are indebted for knowledge, new at the time and valuable in matters of water works distribution systems, acquired by Mr. Brackett as the Chief Engineer of the Metropolitan Water Board—was found to be helpful.

The receipt of this medal has also for me something of a sentimental value, as I did my own first engineering work at the age of sixteen as another, although lowly, member of the engineering force of the Metropolitan Water Board at Clinton. I thank you.

E. SHERMAN CHASE. Another of the honors awarded by this Association is that of honorary membership. Honorary membership in the Association is limited to fifteen. We have on our existing list of honorary members very eminent men in the water works field. Our Executive Committee has now voted the election of another to that list.

Harry E. Jordan, Secretary of the American Water Works Association, was born in Coulterville, Illinois, in the latter part of the last century. He graduated from Franklin College with the degree of Bachelor of Science in the early part of the present century. From the time of his graduation until his appointment as Secretary of the American Water Works Association he was connected with the Indianapolis Water Company, in charge of the quality of the supply of water furnished by that company. During his connection with the Indianapolis Water Company he served on many technical committees of the water works and chemical associations of which he is a member. He was chairman of the joint editorial committee which revised the Standard Methods of Water Analysis used by all water laboratories throughout this country. Since 1936 he has been Secretary of the American Water Works Association, during which time the membership of that Association has, I think, about doubled.

I need give you little additional information with respect to his labors, efforts and accomplishments since 1936, particularly during the past few war years, when he has labored so magnificently to help the water works profession in meeting the problems arising from the war. He well comes within the definition of the requirement for honorary membership, which says that honorary membership shall be granted to men eminent in the water works field, and it gives me

great pleasure, Mr. President, members of the Association and guests, to present to you, Harry E. Jordan, Honorary Member of the New England Water Works Association.

HARRY E. JORDAN. This is a most extraordinary circumstance. Pardon my confusion. Suddenly yesterday afternoon I decided to come to this meeting. I walked down the hall a while ago and found Sherman Chase wanting me to sit beside him at luncheon. I wondered why the waiter was so solicitous about bringing me coffee, but now I understand.

I tremendously appreciate the honor you have done me, and I particularly appreciate the fact that my good friend, Sherman Chase, broke the news to me and to you.

THE CHAIRMAN. We have another distinguished guest with us today. At this time I wish to introduce Samuel B. Morris, President of the American Water Works Association.

SAMUEL B. MORRIS. President Clark, members of the New England Water Works Association, and guests:

I can assure you that it is a great pleasure for me to convey to you the greetings of the American Water Works Association. We have been working with you for a number of years, particularly during these war years, when there has been so much which had to be done in the revamping of specifications and making of plans for the postwar period. I will not say much of the work of the Committee on Water Works and Sewage Development, because that will be presented to you. But here is something very near to my heart because I feel that there is no field of endeavor which is more closely wrapped up in the welfare of communities and of individual citizens than high quality of water supply and excellent sewage disposal. With those two fields represented by this committee, we hope to carry before the country the "Blueprint Now" idea, so that cities and towns may prepare plans in order that immediate construction can take place of those items that are needed in the postwar period. Water works and sewerage are elements that are needed irrespective of what takes place in the first months after the war is over. If there is a large expansion of the consumer goods industry, which we all hope will take place promptly,

we must meet those needs, and if there is a falling off of employment due to those returning from the front there is an excellent opportunity of putting these men to work promptly. I believe, therefore, that there is no better field for prompt work toward recovery when the war is over than the field of water and sewage works development.

I am most happy to be with you.

SECRETARY GIFFORD. The Executive Committee has admitted to membership the following:

Members: Edward J. Beckwith, Waste Water Surveyor, Water Division, Boston, Mass.; John Edward Cox, Water Works, Hamilton, Mass.; Robert Alden Glines, Water Department, Danvers, Mass.; Chester J. Ginder, Civil Engineer, Metropolitan District Water Supply Commission, Boston, Mass.; Irving S. Hazard, Clerk of North Kingston Water Commission, Wickford, R. I.; John F. Kenney, Inspector, Water Division, Boston, Mass.; Hugh McCauley, District Foreman, Water Division, Boston, Mass.; Frederick T. O'Hara, Superintendent, Water Department, Billerica, Mass.; Richard T. Ricker, Water Engineer, Malden, Mass.; Norman Stanley Stearns, Senior Sanitary Engineering Aid, Massachusetts Department of Public Health, Boston, Mass.; Henry M. Wilkins, Civil Engineer, Massachusetts Department of Public Health, Boston, Mass.; Ernest L. Morse, Superintendent, Water Department, Manchester, Conn.; and Charles E. Lane, Water Department, Orange, Mass.

Corporate Members: Town of Ipswich Water & Light Department, Ipswich, Mass.

Associates: Payne Dean & Co., manufacturers of electrical and mechanical valve operating mechanisms, Laconia, N. H.; The Dorr Company, Inc., equipment for water treatment plants, New York, N. Y.; Ferguson & Pascoe, manufacturers of water leak detectors, etc., Newark, N. J.; and The Preload Company, concrete tanks, etc., Boston, Mass.

Afternoon Session

Captain Charles T. Dickeman and Lieutenant (jg) D. H. Bennett, CEC, U.S.N., Naval Advance Base Depot, Davisville, R. I., gave talks on "Water Supply Equipment and Facilities for Advance Bases

of the U. S. Navy." Lieutenant Bennett illustrated his talk with colored lantern slides.

A paper "The Office of War Utilities Program for Coöperation with the Water Industry," was read by Arthur E. Gorman, Director, Water Division, Office of War Utilities, War Production Board, Washington, D. C. Mr. H. Lloyd Nelson, Principal Engineer of the Office of War Utilities, supplemented Mr. Gorman's paper. The paper was also discussed by Horace J. Cook, Theodore L. Bristol, Arthur L. Shaw, and Linn H. Enslow.

The CHAIRMAN announced the sudden death of Mr. Frank P. Hall of Athol, Mass.

WEDNESDAY, SEPTEMBER 29, 1943

Morning Session

A paper "Hydraulics of Distribution Systems—Some Recent Developments in Methods of Analysis," was read by Thomas R. Camp, Associate Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass. The paper was discussed by Harold A. Thomas, Jr., Harold W. Griswold, William W. Brush, and Edwin B. Cobb.

A paper "Some Observations on Water Supplies for Air Raid Fires," was read by Horatio L. Bond, Chief Engineer, National Fire Protection Association. William W. Brush, Harold W. Griswold, Hugh McLean, Samuel B. Morris, and Linn H. Enslow took part in the discussion.

A sound motion picture in color, "Oil for War," showing the construction by War Emergency Pipeline, Inc. of "Big Inch" (1500 miles of 24-inch diameter pipe) for transportation of oil from Texas to the Eastern Seaboard, was presented through the courtesy of The Barrett Division, Allied Chemical and Dye Corporation.

A sound motion picture, "Emergency Chlorination Methods," prepared in connection with Emergency Water Service Training Schools under the New York State Mutual Aid Plan for Water Service, was presented through the courtesy of the New York State Department of Health.

Afternoon Session

Vice-President Karl R. Kennison in the Chair.

REPORT OF TELLERS OF ELECTON

Total Ballots Cast	254	
Defective Ballots	1	
For President, Horace L. Clark		253
For Vice-Pres., Harold W. Griswold		252
For Director, Arthur C. King		251
For Treasurer, Frank J. Gifford		250
For Treasurer, Scattering		1

(*signed*) GEORGE G. BEAN
THEODORE L. CATE
GEORGE E. MANN

The PRESIDENT. I wish to thank the members of the New England Water Works Association for electing me to the office of President. I feel that it is a very high honor and shall do my best to justify your confidence in me.

The untimely death of Harold L. Brigham, who was elected to the presidency of the New England Water Works Association a year ago, left the Association without the services of an able and untiring worker in its behalf. His advice and counsel were sorely missed during the critical year just passed.

The members of the Association need not be told that water is one of the basic needs of all manufacturing plants and without it our huge production of war material could not be accomplished. The aim of each and every one of us has been to supply water of such quality and quantity that no military or naval installation or essential plant has had to slow down production for lack of this prime necessity.

This has been a year when the regular activities of the Association have given way to matters connected with the war effort. It has been the aim of the Executive Committee and the Program Committee to keep you informed of the latest developments in connection with civilian defense, the War Production Board's rulings, and other governmental activities affecting water supply. This will be the policy of the committees for the duration, which we trust will not be long.

The Association has made arrangements to issue bulletins at irregular intervals on matters of interest in connection with new developments in the water works field. Agreements have also been made

with the American Water Works Association and the Maine Water Utilities Association to furnish the New England Water Works Association members with their bulletins in order to avoid duplication of effort.

I wish to thank the other officers and Mr. Joseph Knox, Chairman of the Program Committee, for their help during the past year. It has been a pleasure to work with them in forwarding the interests of the Association.

Finally I wish to express my thanks to the Water and Sewage Works Managers Association for making this Annual Meeting a success.

The Committee on Post War Activities presented a progress report.

WARREN J. SCOTT. In line with the suggestions made by Mr. Chase's committee, I would like to offer the following motion:

That the Committee on Post War Activities be continued, to work with the similar committee of the New England Sewage Works Association and to serve as a New England Regional Joint Committee of the National Water Works and Sewage Works Development Committee.

The motion was duly seconded and carried.

A talk on "Activities of Committee on Water and Sewage Works Development," was given by E. L. Filby, Field Director.

A paper on "Public Works After the War," was read by Elisabeth M. Herlihy, Chairman Massachusetts State Planning Board, Member Massachusetts Emergency Public Works Commission.

A talk on "Post War Planning in Industrial New England," was given by Dudley Harmon, Executive Vice-President, New England Council, and Regional Vice-Chairman, The Committee for Economic Development.

(Adjourned)

ANNUAL REPORT OF THE SECRETARY

Mr. President and Gentlemen of the New England Water Works Association: The Secretary submits herewith the following report of the changes of membership during the past fiscal year, and the general condition of the Association.

The present membership is 787, constituted as follows: 8 Honorary Members, 642 Members, 1 Junior Member, 114 Associate Members, and 22 Corporate Members.

MEMBERSHIP

September 1, 1941. Honorary Members, Total		9		
Withdrawals:				
Died	1	1	8	
Elected	0		0	8
September 1, 1941. Members, Total		656		
Withdrawals:				
Resigned	18			
Died	13			
Dropped by Executive Committee	3	34	622	
Elected:				
September, 1942	7			
October, 1942	1			
November, 1942	4			
January, 1943	3			
February, 1943	2			
March, 1943	1			
May, 1943	1		19	
Reinstated:				
September, 1942	1		1	642
September 1, 1941. Juniors, Total		1		
Withdrawals	0	0	1	
Elected	0		0	1
September 1, 1941. Associates, Total		121		
Withdrawals:				
Resigned	5			

Dropped by Executive Committee	2	7	114	114
September 1, 1941. Corporates, Total		21		
Withdrawals:				
Resigned	1	1	20	
Elected:				
September, 1942	2		2	22
				787
September 1, 1943. Total Membership				787
September 1, 1942. Total Membership				808
Net Loss				21

ELECTIONS

Members

September 14, 1942. Simon P. Carman, Guy E. Griffin, Harry L. Kinsel, Richard H. Royce, Samuel O. Swartz, Elmer P. Tribou, Glen S. Weeks, and Howard C. Mandell (Reinstatement). (8)

October 22, 1942. J. Stanley McClenahan (1).

November 19, 1942. Patrick J. Doran, Charles B. Hardy, Eugene F. Shyne, and Roy W. Smith. (4)

January 21, 1943. Edwin B. Cobb, Edwin M. Howard, and Ellsworth A. Richardson. (3)

February 18, 1943. Richard P. Barstow and Frank J. Thiery. (2)

March 18, 1943. Chester E. Bradley.

May 20, 1943. Frederick Timpson.

Corporate Members

September 14, 1942. Birmingham Water Co. (Derby, Conn.) and Board of Water Commissioners, Milton, Mass. (2)

WITHDRAWALS

Members

Resigned: Carter S. Cole, Harry B. Collins, Daniel J. Donovan, John W. Draper, Ernest E. Erickson, Geo. F. Gardiner, Frederick E. Green, William A. Harris, Albert J. Lamarre, Albert E. Lavery, E. J. Looney, Charles R. Moore, Marshall B. Palmer, Frederick W. Peet, Joseph A. Ross, Nat S. Stevens, Lewis A. W. Swett, and H. E. Wolbert. (18)

Died: John W. Alvord, Arthur Boniface, Harold L. Brigham, A. W. F. Brown, Arthur H. Coy, John H. Howland, Stuart K. Knox, Walter E. Lautz, Hugh J. McLaughlin, Charles T. Main, Patrick S. Nugent, Ralph L. Pollard, Robert Spurr Weston, and Edgar K. Wilson. (14)

Dropped by Executive Committee. Ralph C. Lingley, Joseph L. O'Brien, and Alexander Birnie. (3)

Associates

Resigned: The Allpax Co., Atlantic Steel Co., Cohoes Rolling Mill Co., Continental Pipe Mfg. Co. Inc., and Reilly Tar & Chemical Corp. (5)

Dropped by Executive Committee: Activated Alum Corp. and Water Leak Detector Co. (2)

Corporates

Resigned: Berlin Water Works.

RECEIPTS FOR THE FISCAL YEAR SEPTEMBER 1, 1942 TO SEPTEMBER 1, 1943.

Entrance Fees			$ 81.50
Annual Dues:			
Members	$2,673.51		
Corporates	250.00		
Associates	1,590.00		
Juniors	3.00	$4,516.51	
Fractional Dues:			
Members	$ 45.00		
Associates	5.00	50.00	
Past Dues:			
Members	$ 201.00		
Associates	160.00	361.00	
1943-1944 Dues:			
Members	$ 1.50	1.50	
Total Dues			4,929.01
Dividends and Interest			298.86
Advertisements			3,080.00
Subscriptions			444.00
Journals			43.75
Reprints			10.00
Membership Certificates			6.00
Sundries			47.12
Total Receipts			$8,940.24
There is due the Association:			
Entrance Fees	$ 4.50		
Dues	677.00		
Advertisements	23.00		
Subscriptions	32.00		736.50
Total			$9,676.74

Dues of 25 members who are in our armed forces or in enemy occupied countries have been remitted for the duration.

Respectfully submitted,

FRANK J. GIFFORD, *Secretary*

ANNUAL REPORT OF THE TREASURER

Boston, September 16, 1943

To Frank J. Gifford, Treasurer,
New England Water Works Association,
Boston, Massachusets.

We have examined the statement of assets and funds and the statement of cash receipts and disbursements of the general fund of the New England Water Works Association for the fiscal year ended August 31, 1943. In connection therewith we have reviewed the accounting procedures of the association and have examined accounting records of the association and other supporting evidence, by methods and to the extent we deemed appropriate.

We traced all recorded receipts into the depositary banks, verified the general fund bank account and petty cash fund as at August 31, 1943, and examined properly approved vouchers for all disbursements. We also verified by direct communication the investment funds on deposit in savings banks, and on September 8, 1943 we examined the United States War Savings Bonds at the First National Bank of Boston.

In our opinion, the accompanying statement of assets and funds and the note thereon and the related general fund cash statement present fairly the position of the New England Water Works Association at August 31, 1943, and the recorded cash receipts and disbursements for the fiscal year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

(*signed*) SCOVELL, WELLINGTON & COMPANY

STATEMENT OF ASSETS AND FUNDS (EXHIBIT A)
As at August 31, 1943

Assets

Cash in Banks, Invested Funds	
Farmers and Mechanics Savings Bank, Framingham, Massachusetts	$1,068.46

Franklin Savings Bank, Boston, Massachusetts	1,000.00	
Haverhill Savings Bank, Haverhill, Massachusetts	1,000.00	
Home Savings Bank, Boston, Massachusetts	1,000.00	
Mechanics Savings Bank, Reading, Massachusetts	1,000.00	
Pentucket Savings Bank, Haverhill, Massachusetts	1,000.00	
The People's Savings Bank, Worcester, Massachusetts	1,000.00	
Suffolk Savings Bank, Boston, Massachusetts	1,000.00	8,068.46
Securities		
United States War Savings Bonds G 2½, 1954		10,000.00
Total Invested Cash and Securities		18,068.46
General Fund		
Cash, First National Bank of Boston	2,507.90	
In Office	50.00	
	2,557.90	
Furniture and Fixtures	1,180.00	3,737.90
		$21,806.36
Funds		
Invested Funds		$18,068.46
General Fund		
Balance, August 31, 1942	5,000.50	
Deduct Excess of Disbursements over Receipts, Exhibit B	1,262.60	
Balance, August 31, 1943		3,737.90
		$21,806.36

Note: The statement above, prepared on a cash basis, includes dues received in advance, $1.50, collection of salary paid in advance, $125, and employees' withholding tax, $31.20. It does not reflect the following:

Accounts Receivable, Dues and Initiation Fees	$ 697.50
Due on Account of Advertising and Other Miscellaneous Charges	55.00
	$ 752.50

No depreciation has been taken on Furniture and Fixtures.

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS (EXHIBIT B)

General Fund

For the Year Ended August 31, 1943

Receipts (exclusive of dues received in advance, collection of salary paid in advance, and employees' withholding tax)			
Initiation Fees		$ 81.50	
Dues, 1942-1943 and Prior Years		4,927.51	
Interest		298.86	
From Publication of JOURNAL			
Advertisements	$3,080.00		
Subscriptions	444.00		
Sale of JOURNAL	43.75		
Sale of Reprints	10.00		
Sale of Halftones, Electros, etc.	47.12	3,624.87	
Miscellaneous			
Membership Certificates		6.00	
Total Receipts			$8,938.74
Disbursements			
Publication of JOURNAL			
Printing	2,766.39		
Plates	259.21		
Reporting	447.72		
Reprints	34.43		
Stationery and Postage	139.54		
Editor's Salary	500.00		
Standard Specifications	73.13		
Sundry	14.26	4,234.68	
Office and General			
Certificates of Membership	3.53		
Secretary's Salary	400.00		
Assistant to Secretary—Salary	1,612.50		
Treasurer's Salary	100.00		
Treasurer's Bond	19.62		
Printing, Postage and Stationery	216.47		
Office Supplies and Expense	233.98		
Office Rent	1,200.00		
Electricity	59.28		

Telephone and Telegraph	176.61		
Auditing	65.00		
Social Security Taxes	122.57		
Office Assistance	145.00		
Printing—Membership List	487.50		
Inventory Survey Expense	169.50		
Sundry	117.04	5,128.60	
Meetings and Committees			
Badges	31.39		
Water Works School	100.00		
Printing, Postage and Stationery	654.86		
Convention Expense	24.63		
President's Expense	35.00		
Sundry Expense	149.68	995.76	
Total Disbursements			10,359.04
Excess of Disbursements over Receipts (exclusive of dues received in advance, collection of salary paid in advance, and employees' withholding tax)			1,420.30
Dues Received in Advance		1.50	
Collection of Salary Paid in Advance		125.00	
Employees' Withholding Tax		31.20	157.70
Excess of Disbursements over Receipts, Exhibit A			1,262.60
Balance, General Cash, August 31, 1942			3,820.50
Balance, General Cash, August 31, 1943			
Represented by			
Cash in First National Bank of Boston		2,507.90	
Cash in Office		50.00	
			$2,557.90

ANNUAL REPORT OF THE EDITOR

To the New England Water Works Association:

The Editor submits herewith the following report for the year ending August 31, 1943.

As has been customary in the past, the tables of financial figures, accompanying the report, are based upon total charges and accounts receivable, rather than actual cash received or disbursed. A detailed statement of the receipts and disbursements on account of the September and December, 1942, and March and June, 1943, issues of the JOURNAL is included in the Report of the Treasurer.

STATEMENT OF MATERIAL IN SEPTEMBER AND DECEMBER, 1942, AND MARCH AND JUNE, 1943, ISSUES OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION

	Papers	Proceedings	Total Text	Index	Advertisements	Cover & Contents	Insert Plates	Total	Total Cuts
Sept., 1942	132	8	140	0	35	4	1	181	11
Dec., 1942	98*	32	130*	10	36	4	0	180*	0
March, 1943	72	6	78	0	36	4	1	119	20
June, 1943	90	4	94	0	38	4	0	136	3
Total	392*	50	442*	10	146	16	2	616*	34

*Exclusive of Revisions in Specifications for Elevated Steel Water Tanks, Standpipes, and Reservoirs (2 pages), Proposed Specifications for coal-tar-dip coating for Cast Iron Pipe and Fittings (10 pages), and Tentative Specifications for Cold Water Meters (16 pages).

Table 2 gives a comparison of the JOURNAL for the past year with preceding years.

Size. The four issues contained 616 pages, of which 442 were text. The December issue also contained 28 pages of Specifications.

Cost. The gross cost of the JOURNAL was $4,234.68, equivalent to $5.31 per member; the net cost was $609.81, equivalent to $0.76 per member.

Reprints. Reprints of papers have been furnished to authors at cost.

TABLE 2.—COMPARISONS OF JOURNALS OF THE NEW ENGLAND WATER WORKS ASSOCIATION. FOUR ISSUES FOR FISCAL YEAR ENDING AUGUST 31.

	1934	1935	1936	1937	1938	1939	1940	1941*	1942†	1943**
Average edition (copies printed)	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,175
Average membership	796	786	770	772	785	795	796	800	803	798
Circulation at end of year	928	918	903	920	943	946	967	943	982	969
Pages of text	499	470	477	423	510	488	565	540	575	442
Pages of text per 1,000 members	627	598	619	561	650	614	710	675	716	554
Total pages, all kinds	645	643	642	627	699	670	762	733	757	616
Total pages, per 1,000 members	811	808	834	812	890	843	957	918	943	772
GROSS COST:										
Total	$5,411.30	$4,780.75	$5,880.68	$5,040.86	$4,658.05	$4,119.30	$3,846.46	$4,415.00	$4,053.47	$4,234.68
Per copy	1.23	1.09	1.35	1.23	1.06	0.94	0.87	1.00	0.93	0.90
Per page	8.39	7.54	9.16	8.04	6.66	6.15	5.05	5.66	5.36	6.87
Per member	6.80	6.08	7.64	6.53	5.93	5.18	4.33	5.52	5.05	5.31
Per member per 1,000 pages	10.53	9.46	11.89	10.41	8.49	7.13	6.34	7.53	6.67	8.61
Per member per 1,000 pages of text	13.62	12.93	16.01	15.01	11.63	10.61	8.55	10.21	8.78	12.01
NET COST:										
Total	$1,916.27	$1,332.99	$1,499.58	$489.13	$539.21	$306.77‡	$618.37‡	$276.54	$534.72	$609.81
Per copy	0.44	0.30	0.34	0.11	0.12	0.07‡	0.14‡	0.06	0.12	0.13
Per page	2.97	2.07	2.34	0.78	0.77	0.46‡	0.81‡	0.38	0.71	0.99
Per member	2.41	1.70	1.95	0.63	0.69	0.39‡	0.78‡	0.35	0.67	0.76
Per member per 1,000 pages	3.73	2.64	3.03	1.01	0.98	0.58‡	1.02‡	0.47	0.88	1.24
Per member per 1,000 pages of text	4.83	3.61	4.08	1.46	1.35	0.80‡	1.37‡	0.64	1.16	1.73

*Including comprehensive index, 1882 to 1939, and 102 pages of standard specifications.
‡Profit.
†Including 45 pages of standard specifications.
**Including 28 pages of standard specifications.

Circulation. The present circulation of the JOURNAL is:

Members, all grades	787
Subscribers	122
Exchanges	22
Advertisers	38
Total	969

JOURNALS have been sent to all subscribers and to advertisers.

Respectively submitted,

(*signed*) GORDON M. FAIR, *Editor.*

ANNUAL REPORT OF THE FINANCE COMMITTEE

August 28, 1943

To the Executive Committee of the New England Water Works Association:

Gentlemen:

In preparing a budget for the ensuing year your Committee has studied the receipts and expenses of the Association for the past 12 months, and wishes to present the following information.

REVENUE FOR 1942-1943

	Budget	Actual	Difference
Initiation Fees	$ 150.00	$ 81.50	—$ 68.50
Dues	5,300.00	4,929.01	— 370.99
Interest and Dividends	300.00	298.86	— 1.14
JOURNAL	3,600.00	3,644.87	+ 44.87
Miscellaneous	75.00	16.76	— 58.24
	$9,425.00	$8,971.00	—$454.00

EXPENDITURES FOR 1942-1943

	Budget	Actual	Difference
Office	$4,000.00	$4,983.01	$983.01 Overdraft
JOURNAL	4,000.00	4,254.68	254.68 Overdraft
Meetings and Committees	1,300.00	995.76	304.24 Balance
Miscellaneous	125.00	0.00	125.00 Balance
	$9,425.00	$10,233.45	$808.45 Overdraft

As the receipts total $454.00 less and the expenditures $808.45 more, this means a deficiency of $1,262.45. This was partially offset by an extra $500.00 voted to assist in compiling a list of wartime materials, giving a net loss of $762.45. The extraordinary items which have caused this overdraft are: the publishing of the membership list $555.00; representative to Washington (2 trips) $116.00; and the costs of Defense School $168.00. These expenses total $839.00 and were not included in the 1942-43 budget.

As the general fund (checking account), as of August 28, 1943, amounted to $2,508.05, this deficiency can easily be taken care of.

In drafting a budget for the year 1943 and 1944 more difficulties were encountered. On the receipt side, there is no reason to expect that there will be any increase in the number of new members. This year's income from initiation fees was $81.50. The Committee has estimated even less for the coming year, namely $60.00. The amount received from dues was $4,929.01. The estimate for next year is $5,000.00. The interest and dividends are fairly well fixed at about $300.00. The estimated receipts from the JOURNAL are the same $3,600.00, and miscellaneous receipts $25.00.

RECAPITULATION—ESTIMATED REVENUE FOR 1943-1944

Initiation Fees	$ 60.00
Dues	5,000.00
Interest and Dividends	300.00
JOURNAL	3,600.00
Miscellaneous	25.00
Total	$8,985.00

In the estimated expenditures, $4,800.00 is suggested for the office as compared with $4,983.01 spent this year. However, there was about $200.00 extra cost when an extra girl was employed last fall at the time of the change of Assistant Secretaries. The expense for the JOURNAL cannot change greatly so the sum of $4,200.00 was allowed. With the increased tempo of war committee work, $200.00 additional was allotted to the use of committees and meetings. For miscellaneous and unforeseen expenses the estimate was $250.00.

RECAPITULATION—ESTIMATED EXPENDITURES FOR 1943-1944

Office	$ 4,800.00
JOURNAL	4,200.00
Meetings and Committees	1,200.00
Miscellaneous	250.00
Water & Sewage Works Development Committee	700.00
	$11,150.00

The last item has been included at the request of the members representing the New England Water Works Association on the Committee on Water and Sewage Works Development. The intensive study and planning by this group for immediate action at the close of the war has necessitated the establishment of an office with a field director in charge. The estimated budget for this work with its travel expenses, promotionoal literature, mailing, etc., has been placed at $18,000.00. The Water and Sewage Manufacturers Association is taking care of $10,000.00 of this amount. The remainder has been divided pro rata according to membership between the American Water Works Association, Federation of Sewage Works Associations and the New England Water Works Association. This Association has been asked to bear its share which is $588.00. This is certainly a small part of the whole cost and should be borne willingly. Your Finance Committee feels that $700.00 should be appropriated, allowing an overlay for the expenses of the representatives of this Association.

With estimated receipts of only $8,985.00, this will mean a loss for the year of $2,165.00.

Throughout the prosperous life of the Association, there has been an accumulation of securities and bank deposits which now total $18,068.46. There is, in addition, a general fund (checking account) of $2,508.05. This has been set aside for good and sufficient reasons. The Committee can see no better use for a small part of the money than to spend it to survive this great emergency, keeping the Association functioning and doing its share in the war effort.

This proposed budget for 1943-44 is respectfully submitted to the Executive Committee.

As the uncollected dues for the present year total $625.00, the Finance Committee recommends that a special effort be made to collect as much as possible of this amount.

The usual accountants will be employed to audit the books of the Treasurer, and their findings will be included in his report.

(*signed*) HORACE J. COOK, *Chairman*
DANIEL M. SULLIVAN
WALTER B. BUSHWAY

ANNUAL REPORT OF THE COMMITTEE ON THE LIBRARY

September 28, 1943

To the New England Water Works Association: Your Library Committee, as usual, has little to report. There has been an apparent increase in the use of the library this year. Except for regular periodicals and reports there have been no material additions to the reference matter on its shelves.

We again urge that the members make greater use of the facilities of our library and of the quiet and comfortable room in which it is housed.

Respectfully submitted,

(*signed*) E. SHERMAN CHASE, *Chairman*
FRANCIS A. KINGSBURY

ANNUAL REPORT OF THE COMMITTEE ON RECIPROCAL RELATIONS WITH THE INSTITUTION OF WATER ENGINEERS

September 28, 1943

To the New England Water Works Association: Due to the war, your Committee on Reciprocal Relations with the Institution of Water Engineers of England has little to report.

As in previous years, we have maintained correspondence with Mr. Gourley, Chairman of the corresponding committee of the Institution of Water Engineers and with Mr. Cronin, Chief Engineer of the London Metropolitan Water Board. Publications of the Institution consisting of a monthly journal and a yearly volume of transactions, are received regularly by our library.

It is interesting and encouraging to note that the regular meetings of the Institution, which were discontinued in 1939, following the outbreak of the war, were resumed this past spring, and that the offices of

the Institution, which were moved to the country at the time of the "Blitz," have been returned to London.

We recommend the continuation of our Committee with the confident hope that more active relations between the two associations will be resumed in the not distant future.

Respectfully submitted,
(*signed*) E. SHERMAN CHASE, *Chairman*
LELAND CARLETON
PERCY A. SHAW

LELAND G. CARLETON. I would like to present a motion for action at this session:

That the New England Water Works Association, through its President, transmit its cordial greetings to the President of the Institution of Water Engineers, expressing great satisfaction at the more nearly normal way in which the Institution can now function as compared with the past few years.

The motion was duly seconded and carried.

ANNUAL REPORT OF THE COMMITTEE ON COMMITTEES

September 10, 1943

To the New England Water Works Association: This committee appointed by the Executive Committee of the Association to promote coördination of committee activities in the Association and to promote the establishment of new technical committees where this seems advisable, submits a brief report. Again we are in a war year and committee activities have had to be curtailed. The committee on committees has, however, continued its usual practice of communicating with the various committee chairmen to secure their ideas as to continuance of the committees and their plans with regard to reports.

On the basis of returns from the committees, it is recommended that the following committees be discontinued:

Committee on Water Works Education (work to be continued by Committee on Technical Program).

Committee to Coöperate with the Regional Office of Civilian Defense (work to be carried out by officers of the Association unless some further need arises for such a committee).

No technical committee is planning to submit a final report at the sixty-second annual meeting.

The following committees will either submit progress reports, or in the opinion of this committee they should be continued, even though it is probable that work on the committee reports will be of necessity lessened under war conditions.

Finance Committee.

Committee on Technical Program.

Committee on New Members.

Committee on Code for Pressure Piping.

Committee on Coefficients of Friction in Pipe Lines.

Committee on Specifications for Cast Iron Pipe and Special Castings (Sectional Committee under A.S.A.).

Committee on Standardization of Pipe Flanges and Fittings (Sectional Committee under A.S.A.).

Committee to Investigate Grounding of Currents on House Plumbing (Coöperating with the American Research Committee on Grounding.

Committee on Meter Specifications (Joint Committee with A.W.W.A.

Committee on Rainfall and Yield of Drainage Areas.

Committee on Water Quality Tolerances for Industrial Uses.

Committee on Library.

Legislative Committee.

Committee on Reciprocal Relations with the Institution of Water Engineers (England).

Committee on Survey of Ground Water Supplies in New England.

Committee on Sluice Gates.

Committee to Report on Developments in Our Knowledge of Corrosion and Its Mitigation.

Committee on Committees.

Committee on Cathodic Protection of Steel Tanks and Standpipes.

Committee on Hydrant Specifications (Joint Committee with A.W.W.A.).

Committee on Water Works Coöperation in Defense.

Committee on Post War Activities.

Committee on Wartime Water Works Information.

Committee on Water and Sewage Works Development (Joint Committee. See below).

Committee on Sanitary Hazards of Interior Piping, Fixtures and Water Storage Within Buildings (Joint Committee with A.W.W.A. See comments below).

Committee on Survival and Retirement Experience with Water Works Facilities.

The chairman of the Committee on Sanitary Hazards of Interior Piping, Fixtures and Water Storage within Buildings has suggested that this committee be discontinued inasmuch as it has been inactive. However, where this is a joint committee with the American Water Works Association, it is recommended that this proposal be discussed by the officers of the two associations before discontinuance.

New Committees. The suggestion has been made by one of the committee chairmen, Mr. E. S. Chase, that a committee be appointed on compensation of water works employees, definition of duties and recruiting of younger men for the profession. All of these subjects appear to be of importance to the water works profession. It is recommended that consideration be given to the appointment of a committee on the recruiting, training, and compensation of water works employees.

Sight should not be lost of the value of keeping the public advised as to what is going on in the water works field and emphasizing the importance of water supply operations and water supply development. The Association could well consider the appointment of a committee on publicity or the adoption of a plan for paid publicity to promote the utilization of the press for this purpose.

The American Water Works Association has discussed the formation of joint committees on "Valve Box Frames and Covers" and "Threads for Underground Service Lines." These should be kept under consideration for joint decision by the two associations.

Procedure as to Committee Designations and Appointments. The Association now publishes a list of committee designations and appointments in the December, 1942, issue of the Association JOURNAL. It is recommended that a policy be adopted whereby the chairman of the committee on committees is notified promptly by the secretary as to any interim committee designations and appointments so as to promote the coördination of committee activities.

War Activities. At the beginning of the year the only committee directly concerned with the war program was the Committee on Water Works Coöperation in Defense. During the year, a Committee on Wartime Water Works Information was appointed. It is suggested that the chairman of the former committee be appointed as a member of the latter committee so as to insure close coördination of the committee activities.

A "Committee on Water and Sewage Works Development" has been appointed jointly by the New England Water Works Association, the Federation of Sewage Works Associations, the American Water Works Association, and the Water and Sewage Works Manufacturers' Association.

In a committee release it is stated that "In the case of the New England area, the existing committees of the New England Water Works Association and the New England Sewage Works Association can function for all six New England States, probably expanding their present membership somewhat and possibly forming state subcommittees through state water works and sewage associations."

The Association has this year appointed a committee on post-war planning and the chairman was appointed as one of the two members of the joint "Committee on Water and Sewage Works Development." Such a close tie-in appears desirable to avoid duplication.

Conclusions and Recommendations. It is recommended that the standing committees listed be reappointed with two or three changes, as outlined above. The times do not appear to warrant extensive committee assignments now except as they relate to the war effort in which water works maintenance is closely involved. Post-war planning in the water works field, however, does appear to merit study now so as to provide a program for cushioning the after-effects of the war; committee assignments in this field are discussed in this report. Possible appointment, now or later, of committees on recruiting, training and compensation of water works employees and on publicity, should be borne in mind.

Respectfully submitted,

(*signed*) WARREN J. SCOTT, *Chairman*
THOMAS R. CAMP
HARRY U. FULLER
ARTHUR C. KING
ARTHUR L. SHAW

PROGRESS REPORT OF THE COMMITTEE ON PRESSURE PIPING

August 5, 1943

Mr. Warren J. Scott
Connecticut State Department of Health
State Office Building
Hartford, Conn.
Dear Mr. Scott:

Referring to your letter dated August 3, to which was attached a questionnaire regarding my report as a representative of the New England Water Works Association on the Sectional Committee on Code for Pressure Piping, I believe the following brief report should be made at the September meeting:

"During the year 1942, the Committee on Code for Pressure Piping issued a revised edition of this code. This was published by the American Society of Mechanical Engineers under date of November 1942. The Code as it now stands includes the following sections:

Section 1 Power Piping Systems
Section 2 Gas and Air Piping Systems
Section 3 Oil Piping Systems
Section 4 District Heating Piping Systems
Section 5 Refrigeration Piping Systems
Section 6 Fabrication Details
Chapter 1 Pipe Hangers, Supports, Anchors, Sway Bracings and Vibration Dampeners
Chapter 2 Pipe Joints Other Than Welded
Chapter 3 Expansion and Flexibility
Chapter 4 Welding of Pipe Joints
Chapter 5 Welded Branch Connections and Fabricated Cast Specials
Section 7 Materials—Their Specifications and Identification"

You will note that the only place the Code would touch the water works industry is in that section dealing with power piping where

steam pumping plants are in use. A number of years ago there was some talk of including a section covering water piping in general. After some discussion at that time it was felt that this should not be done and I believe that it is to the interest of the water works profession that no effort be made to have a section on water piping included in the Code. While it is unlikely that any revision of the Code will be made during the current year I believe the New England Water Works Association should continue to have representation on the Committee.

Yours very truly,

(*signed*) THOMAS F. WOLFE

ANNUAL REPORT OF THE LEGISLATIVE COMMITTEE

To the President and Members of the New England Water Works Association: Your committee respectfully presents the following report of legislative activity in New England during 1943:

The Connecticut member of this committee who is also chairman of the legislative committee of the Connecticut Water Works Association, considered all bills presented in that state.

There were 67 bills presented which it was deemed advisable to oppose, if necessary for defeat. At a cost of about $900.00, counsel was employed to appear at committee hearings to oppose certain of these undesirable bills, and all were defeated.

Three acts of interest were enacted in the State of Maine.

1. Chap. 19 "An Act Relating to Permits by Cities and Towns to Pipe Line Companies." While this act was intended primarily to affect oil pipe lines, it permits water and other utilities to lay pipes in streets and roads subject to approval of design by the town officials having jurisdiction.

2. Chap. 199. "An Act Relating to Municipal Planning and Zoning" permits cities and towns to create planning and zoning boards which shall have control over design and location of all structures, above and below ground, in planned developments.

3. Chap. 262, "An Act to Permit Towns to Create Protected Reserves" permits towns to create funds for use in emergencies and periods of depression and to prevent their expenditure for unauthorized purposes. This is known as the Post War Planning Law, and does not affect water utilities organized as Water Districts or Water Companies.

In Massachusetts, as usual, nearly 2,500 bills were presented to the General Court. All titles were examined and about ten noted for full examination.

Your chairman attended several committee hearings, chiefly those upon five bills of particular interest.

1. An act authorizing cities, towns, and districts, through their water departments, to aid other water departments under the same

privileges, as if working in their own communities and also authorizing payment for such aid and for damage to property sustained by the department rendering such aid.

2. An act authorizing water commissioners and their representatives to enter any premises except dwelling houses within the watershed of their source of supply to ascertain whether rules and regulations are being obeyed.

3. An act providing for the establishment of forest cutting practices, by an unpaid state committee with the director of the forestry department as the executive member. While this act requires large cuttings to be made only under a plan approved by the director exception is allowed for cuttings for utility rights of way, for pastures, cultivation, or building, for an owner's own use and in moderate amounts for sale.

4. Two acts were presented in the hope of opening Lake Cochituate for bathing or fishing. While this is only a reserve supply of the Metropolitan Boston water system, the fact that one bill was enacted serves to show the necessity for constant vigilance by water works men. We believe that amendments to the bill provided limitations making the final form acceptable to the Metropolitan officials.

5. This act authorizes the Department of Public Health to approve the taking of water for public water supply purposes from emergency sources.

In New Hampshire an act was passed giving water works the right to set aside funds, out of money accumulating during the next two years, to be spent for specific projects at a later date. Two or three objectionable bills were defeated.

In Rhode Island and Vermont no legislation of particular interest to water works men was noted.

Respectfully submitted,

(*signed*) ARTHUR C. KING, *Chairman*
SIDNEY S. ANTHONY
THEODORE L. BRISTOL
MADISON H. GOFF
GEORGE A. REED
PERCY R. SANDERS
STEPHEN H. TAYLOR
JAMES V. TURNER

REPORT OF THE COMMITTEE ON WATER WORKS COOPERATION IN DEFENSE

September 28, 1943

To the New England Water Works Association: The Committee on Water Works Coöperation in Defense was constituted largely for the purpose of exchanging information between representatives of the several New England states and suggesting new efforts that might be undertaken by the New England Water Works Association for mutual aid of communities and between states.

Your committee chairman, at the convention in September 1941, outlined in detail the setup of the Massachusetts State Emergency Plan. The activities of the Connecticut Water Works Association and of the Department of Health in Connecticut were described by officials of Connecticut. The activities of the Maine Water Utilities Association were discussed by representatives of those organizations.

At the annual meeting in September 1942, your committee reported in considerable detail as to the warnings of the U. S. Public Health Service following the declaration of war in the matter of protection of water works properties and treatment of water and as to the appointment of state water coördinators in each of the New England states. That report also dealt with the question of inventories, water works schools for the training of chemists and bacteriologists in methods of decontamination of water and food, and the water works schools set up in the states of New York and Maine and by local officials for the training of auxiliary personnel. At the time of the September 1942 report, a critical shortage existed in raw materials from which water works materials are fabricated, and the water works fraternity was urged to actively assist the War Production Board in making surplus materials available to each other and to military establishments and essential war industries.

Conditions During the Past Year

State Water Supply Coördinators. During the past year Major

Howard H. Potter, formerly State Water Supply Coördinator for the State of Maine, has been appointed Sanitary Engineer in the U. S. Public Health Service and detailed to assist the Office of Civilian Defense in the First Region which covers the New England states, an area with which he is quite familiar. His position as State Water Supply Coördinator for Maine has been filled by the appointment of J. Elliott Hale of the State Bureau of Health. In New Hampshire, Percy A. Shaw has been appointed Assistant State Water Coördinator. In Connectcut, Edward E. Minor, Vice President of the New Haven Water Company, has been appointed Associate State Water Supply Coördinator to replace G. E. Lourie, and Samuel W. Bowers of Southington has replaced Mr. Lourie as one of the District Coördinators. The present State Water Supply Coördinators in the New England States are as follows:

J. Elliott Hale, Supervising Sanitary Engineer, State Bureau of Health, Augusta, Maine.

Charles D. Howard, Director, Division of Chemistry and Sanitation, State Board of Health, Concord New Hampshire.

E. L. Tracy, Sanitary Engineer, State Board of Health, Burlington, Vermont.

Arthur D. Weston, Chief Sanitary Engineer, Massachusetts Department of Public Health, State House, Boston, Massachusetts.

Walter J. Shea, Acting Chief, Division of Sanitary Engineering, Rhode Island Department of Health, Providence, Rhode Island.

Warren J. Scott, Director, Bureau of Sanitary Engineering, State of Connecticut, Department of Health, Hartford, Connecticut.

Manuals. In Connecticut, the State War Council, together with the State Department of Health, has prepared a manual entitled "Manual on Emergency Water Supply and Sanitation Measures."

Emergency Organizations. Some progress has been made in the organization of auxiliary groups to assist water works officials in time of emergency by enlisting the services of mechanics, plumbers, and others, although some resistance to this sort of program has been experienced with the water companies.

Water Works Schools. Water works schools have been carried on in Maine by certain Federal agencies and have been of value to local

water works officials. In some of the other states, local officials have carried on schools for their auxiliary water works groups with lectures from state and other officials although the shortage of mechanical personnel who have engaged in war industry or entered the military services has somewhat restricted this activity.

Post-War Planning. Public officials have been cognizant of the need of post-war planning and certain activities are under way to secure legislation for the accumulation of reserve funds to permit the rehabilitation and extension of water works as a field for post-war activity. Water works officials would do well to reduce to writing their plans for the post-war period in order that funds may be utilized for this important sanitation need and so that such works may be undertaken immediately when the opportunity presents itself rather than permitting the diversion of public funds to less desirable and less essential public needs. Some progress in this matter is reported from some of the states.

Water Works Employees. The water works industry in common with other public utilities has suffered a loss of personnel to the military services and war industry. Some water departments have been able to increase wages within Federal restrictions to permit them to bid against private industry to retain the services of water works employees desiring to leave for higher paid war industry positions. In general, municipal water departments have not been able to compete with industry. Water works employees have been drafted and, in certain instances, considerable difficulty has been experienced in convincing local draft boards of the importance of retaining water superintendents and their assistants. While the essential occupations, as defined by the War Manpower Commission, include classifications that would pertain to the more important water works employees, the decision rests primarily with the local draft boards, subject to the individual's rights of appeal.

It is important that water works executives make certain that local draft boards appreciate the importance of a particular man's service to the maintenance of the local water department and the importance of the supply to the community in order that they may be fully informed before final decision is made in regard to any particular water works employee.

Assistance to Local Communities by State Agencies. Two points of view have been presented to your committee with regard to the amount of assistance that should be rendered to local communities during the war period. One state has emphasized the need of maintaining adequate state agencies to aid local officials in solving their problems. Another state has emphasized the need of local officials trying to restrict their requests for assistance from state agencies that are already overloaded with work with greatly reduced personnel. Comment has been made as to the seeming inconsistency of placing trained personnel in service with Federal agencies and returning them to the local areas to perform work similar to that done while in civilian status.

Water Works Material

U-Orders. It is reported from one state that the U-orders when first issued became a source of annoyance, but that following conferences in Washington in April at which representatives of the New England states were present the situation with regard to the U-orders was improved with a better understanding by the War Production Board of the problems involved.

Excess Inventories. It is reported that excess inventories have largely been eliminated but that the water works officials have reasonable residual inventories in at least one of the states. At least four of the New England states have classified total inventories showing water works materials available for mutual aid.

Copper Tubing. Your committee is informed that the War Production Board has frozen all utilities stocks of copper tubing and that controversy has arisen as to the price to be paid for this material. Water utilities had prudently stocked with copper tubing used for services in anticipation of shortage at the then market price and it seems only reasonable that frozen stocks, if captured by government agencies, should be taken over at the price paid unless it can be shown that some unfair practice has prevailed.

Rationing. One of the New England states has reported difficulties arising from the rationing of gas, oil, and rubber. No doubt, almost every water works official has experienced some difficulty in this regard, and although it is probable that local rationing boards appreciate the importance of the water works utility to the community and

have been as lenient in the matter of rationing as the regulations will permit, further classification is probably desirable.

Federal Agencies

Your committee is cognizant of the number of Federal agencies that have undertaken activities in the water works field and of the overlapping of such activities to a considerable extent. In the matter of the Facility Security Program, the U. S. Public Health Service, the Office of Civilian Defense, and the U. S. Army Service Commands are all interested in water works practise to varying degrees. While considerable progress in the coördination of these activities has been brought about, many local state officials are still at a loss to know how best to advise certain of the municipalities in these matters. If proper advice as to protection of public water supplies is to be given by the state authorities, then further clarification of Federal requirements must be forthcoming.

In the matter of procurement of priority for water works materials, at least two Federal agencies are concerned; viz., the War Production Board through its Water Supply Section and the U. S. Public Health Service acting as agent auxiliary to the War Production Board. In certain instances, similar information has been furnished to representatives of these two agencies in duplication of the effort required of the state in rendering assistance.

It is the belief of your committee that the water works officials in the several New England states have, as recommended by your committee in September 1942, acted in close coöperation with Federal and state agencies. They must be forgiven if a certain amount of irritation has been apparent because of duplication of effort.

Respectfully submitted,

(*signed*) Arthur D. Weston (Massachusetts)
Chairman
Theodore L. Cate (New Hampshire)
Harry U. Fuller (Maine)
Warren J. Scott (Connecticut)
Joseph E. Moore (Vermont)
Walter J. Shea (Rhode Island)

PROGRESS REPORT OF COMMITTEE ON POST WAR ACTIVITIES

September 29, 1943

To the New England Water Works Association:

Your Committee on Post War Activities was authorized by the Association at its annual meeting in 1942. Later the Executive Committee appointed a chairman who, in turn, appointed other members representative of various interests and points of view. This committee submitted a Progress Report at the March meeting and sponsored a symposium at the May meeting (See JOURNAL of the New England Water Works Association September, 1943, page 261). A similar committee was authorized by the New England Sewage Works Association at its May meeting, with the chairman of your committee as chairman of its committee.

Early in June, 1943, the Water Works and Sewage Works Manufacturers Association suggested to Acting President Clark of your Association and to the officers of the American Water Works Association and of the Federation of Sewage Works Associations the formation of a national committee to promote objectives in both the water works and sewage works fields similar to those set forth in the Progress Report of your committee. The Water Works and Sewage Works Manufacturers Association also offered to assist in the financing of such a committee to the extent of $10,000.

As a result of this suggestion, Acting President Clark appointed Roger W. Esty of Danvers and the Chairman of this Committee as representatives of the New England Water Works Association to serve on a national committee, if formed. A preliminary meeting of representatives of the four associations was held in Cleveland in June and another in Washington in July. At the latter meeting the committee was organized with Abel Wolman as chairman and Harry Jordan as secretary. The name "Committee on Water and Sewage Works Development" was adopted for this national committee.

At the Washington meeting the committee formulated general

policies, which have been incorporated in a bulletin and distributed to the members of the affiliated associations and to the technical press. A copy of the bulletin is appended.

A third meeting of the Development Committee was held in New York in August, at which meeting E. L. Filby of Kansas City was appointed field director. Mr. Filby began his duties September 1st with an office and secretary at 500 Fifth Avenue, New York City.

In view of the formation of the national committee, your committee has held in abeyance its own activities during the summer in order to learn the policies of the national committee and the manner in which its own activities could be correlated therewith. In this connection you will note from the appended bulletin that the national committee plans the formation of state committees throughout the country. An exception is made in the case of the New England area, where it is proposed that "the existing committee of the N.E.W.W.A. and the N.E.S.W.A. can function for all six New England states, probably expanding their present membership somewhat and possibly forming state subcommittees through state water works and sewage works associations."

In view of the foregoing developments which have taken place since the presentation of the Progress Report of your committee, it would seem advisable for the committees of this Association and that of the New England Sewage Works Association to form a joint committee for the purpose of representing in New England the national Committee on Water and Sewage Works Development. Furthermore, it seems advisable to reorganize and expand this joint committee somewhat in order that it may function efficiently to produce the most good. In this connection it would be well to provide on the committee membership for the state sanitary engineers, ex officio, of each of the New England states. Such a step will be taken if the New England Water Works Association authorizes its committee to act jointly with the committee of the New England Sewage Works Association. Such coöperation was authorized on September 22 by the latter association.

In connection with the functioning of the national committee, the anticipated budget for the period up to June 30, 1944 is $18,000, of which $10,000 will be contributed by the Water Works and Sewage Works Manufacturers Association, leaving $8,000 to be obtained from

other sources. It is proposed that the other three sponsoring associations make up this $8,000 in proportion to their dues income for their fiscal years ending in 1942. On this basis the share for the New England Water Works Association would be $588. The Chairman of your Committee has recommended to the Finance Committee that $700 be allocated to it to provide this $588, together with $112 for additional expenses which may be encountered.

Your Committee recommends:

1. Authorization for joint coöperation with the similar committee of the New England Sewage Works Association.

2. The reorganization of the two committees to permit fullest representation of the various interests concerned, particularly engineering divisions of state health departments.

3. That each member of the Association consider himself an unofficial member of the Committee for the purpose of promoting within its sphere of influence the slogan "BLUE PRINT NOW."

In conclusion, the Committee wishes to advise the Association that if continued, it plans aggressive action during the coming winter and also plans to submit Progress Reports from time to time at the monthly meetings.

Respectfully submitted,

(*signed*) E. SHERMAN CHASE, *Chairman*
THEODORE CATE
RICHARD H. ELLIS
HAROLD W. GRISWOLD
PHILIP J. HOLTON, JR.
HOWARD H. POTTER
F. J. RENY
E. L. TRACY

Committees of the New England Water Works Association
1943-1944

Finance Committee: Walter B. Bushway, Chairman, Mark F. Croker, Allan F. McAlary.

Technical Program Committee: Joseph C. Knox, Chairman, Sidney S. Anthony, E. Sherman Chase, Gordon M. Fair, Paul Howard, Roger Oakman, George A. Sampson, Members of the Executive Committee.

Committee on New Members: Roger Oakman, Chairman, Everett O. Boothby, Joseph N. McKernan, Percy R. Sanders, Ernest J. Sullivan, James V. Turner, Burton L. Winslow.

Sectional Committee on Code for Pressure Piping: Thomas F. Wolfe.

Committee on Coefficients for Friction in Pipe Lines: Elson T. Killam, Chairman, Frank A. Barbour, William W. Brush, Charles W. Sherman.

Committee on Specifications for Cast Iron Pipe and Special Castings (Sectional Committee under the American Standards Association): William R. Conard, Chairman, Arthur L. Shaw.

Committee on Standardization of Pipe Flanges and Fittings (Sectional Committee under the American Standards Association): William R. Conard, Chairman, Frank A. Barbour.

Committee on Water Works Education: Gordon M. Fair, Chairman, Francis H. Kingsbury, Percy R. Sanders.

Committee to Investigate Grounding of Currents on House Plumbing (Coöperating with the American Research Committee on Grounding): George A. Sampson, Chairman, Warren A. Gentner, Arthur V. Harrington, Edward E. Minor.

Committee on Meter Specifications (Joint Committee with the American Water Works Association): Richard H. Ellis, Chairman, Warren A. Gentner, D. H. Hall.

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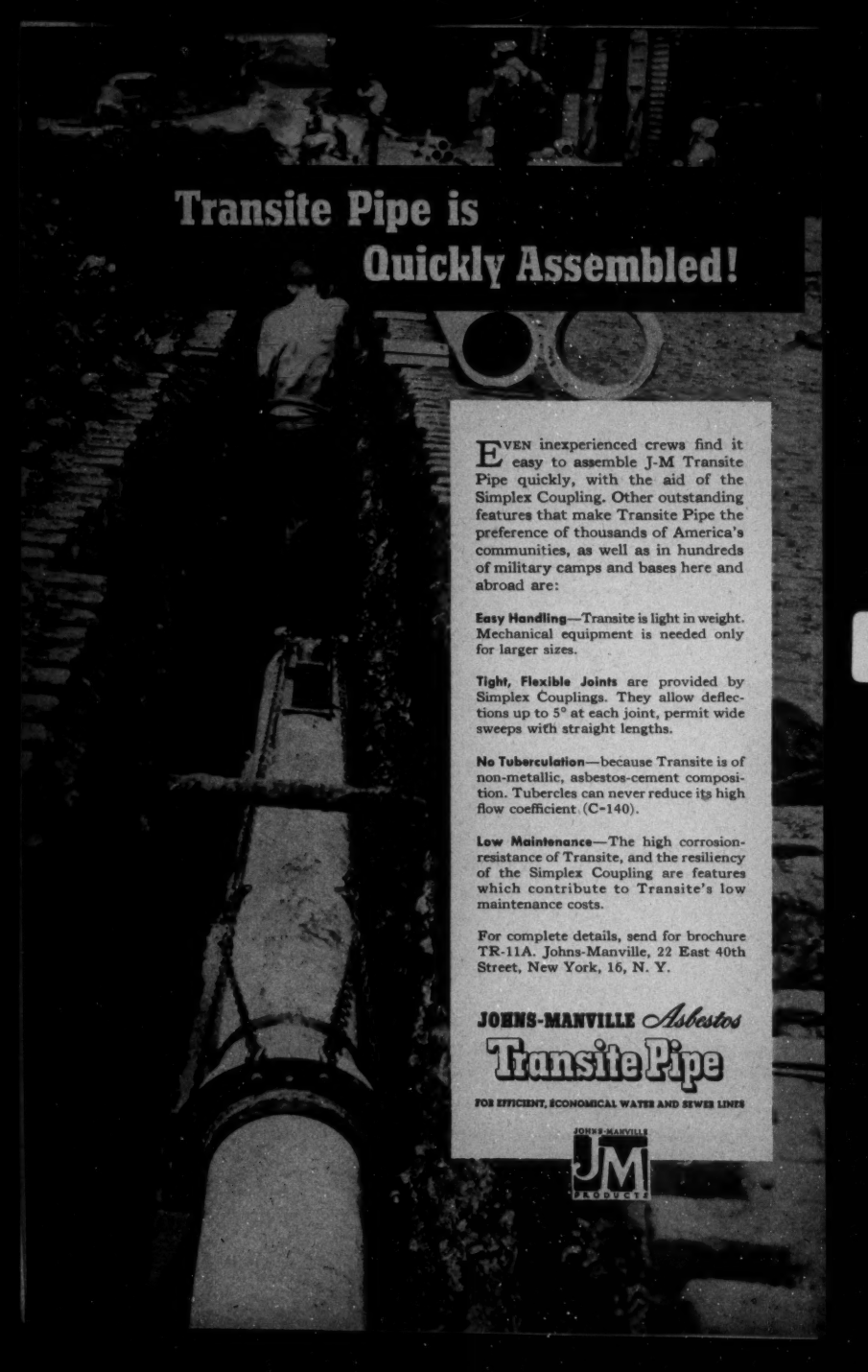

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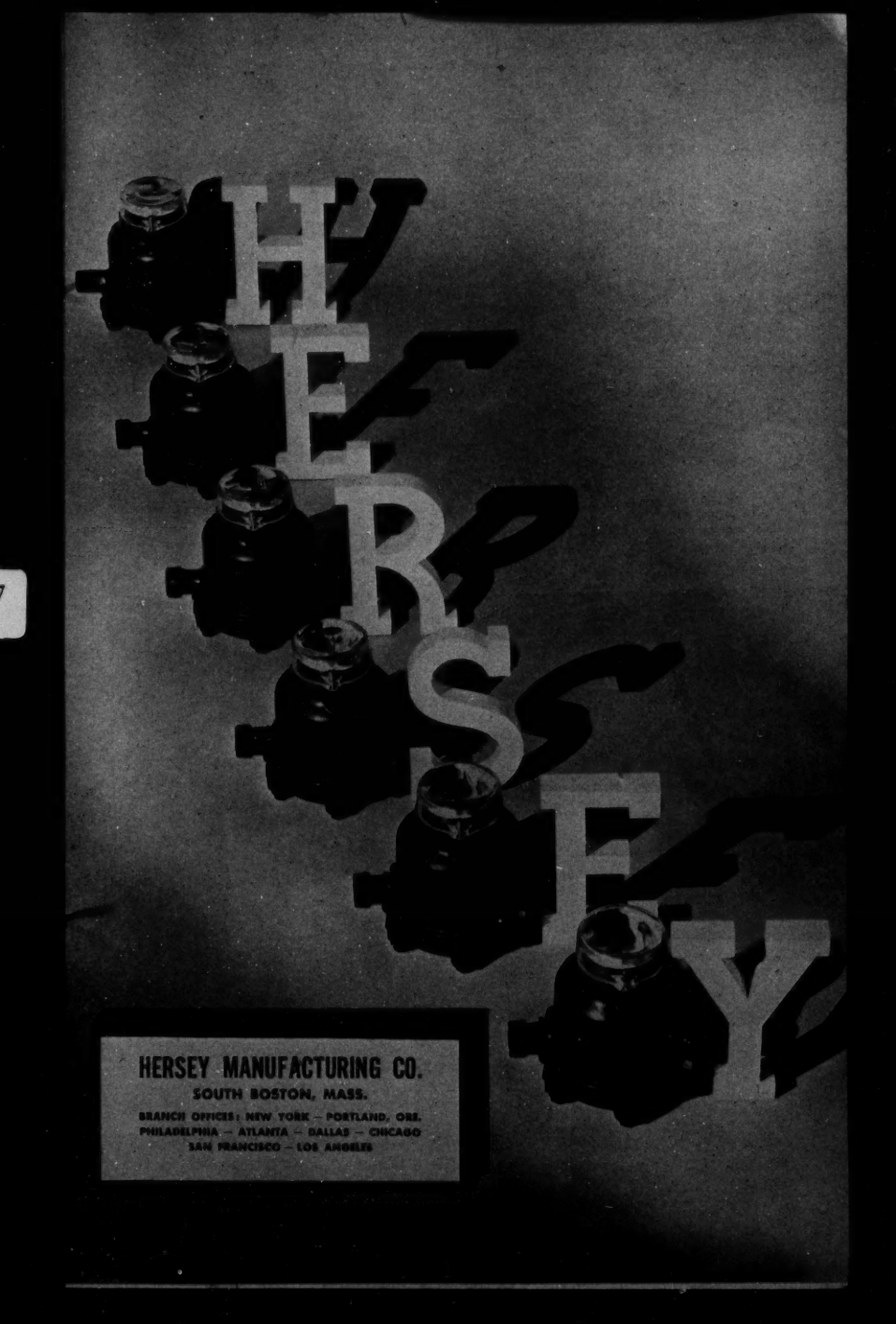

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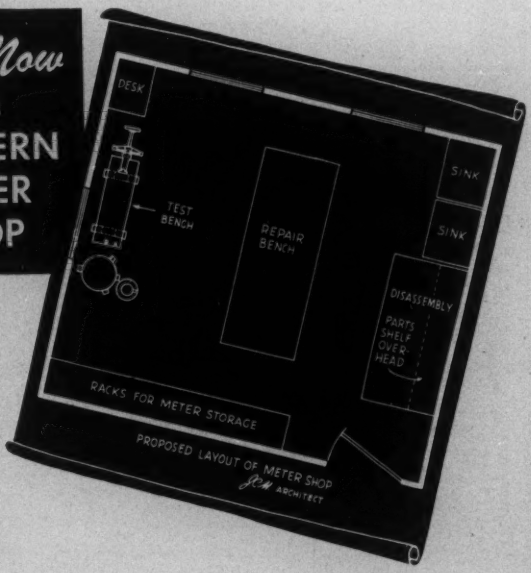

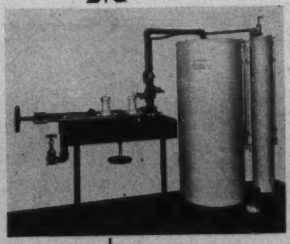

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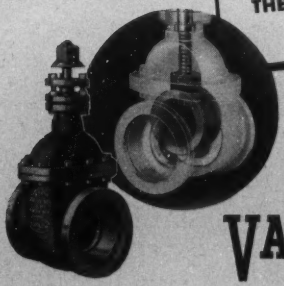

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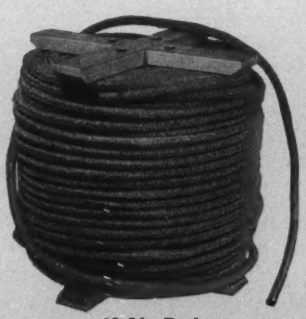

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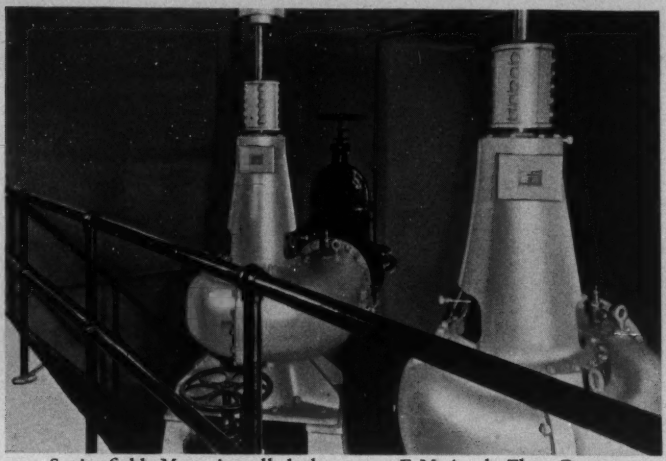

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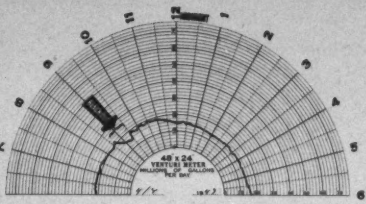

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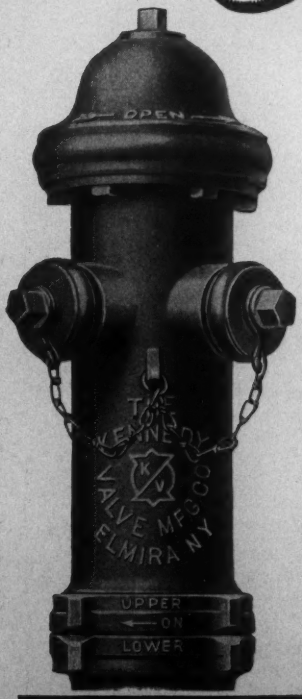

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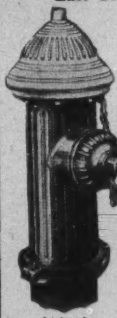

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CENTRIFUGAL PUMPS

DE LAVAL

CENTRIFUGAL WATER WORKS PUMPS

Town of Hanover, Mass. — Pumping Station

When we have won the war, such equipment as shown above will again be available to New England Water Works.

As Engineers and Contractors we hope to have the pleasure of supplying your requirements, at that time, as we have been doing for the past thirty-seven years.

(This is the second of a series of typical installation advertisements.)

TURBINE EQUIPMENT COMPANY OF NEW ENGLAND

80 Federal Street **Phone LIBerty 5993-5994** **Boston, Mass.**

New England Representatives for

DE LAVAL STEAM TURBINE COMPANY

TRENTON, NEW JERSEY

...MAKE FULLY EFFICIENT USE OF *Chlorination*

TODAY you may be making far-sighted plans for a more modern water plant to meet the postwar development of your community.

For that plant naturally you will want the extra safety and flexibility of operation that will be afforded by an installation of the most modern type of chlorinators.

New applications of Break-Point chlorination and potential chlorination will add to the safety and palatability of water. New installations of automatic chlorinators, with chlorine flow recorders, will increase the convenience and surety of treatment. Duplicate chlorinators will assure protection in all emergencies.

In the meantime, Wallace & Tiernan will be glad to help keep your present installation in most effective service, by suggesting methods to get the utmost from chlorinating equipment and by supplying necessary replacement parts. SA-150-S

"The Only Safe Water is a Sterilized Water"

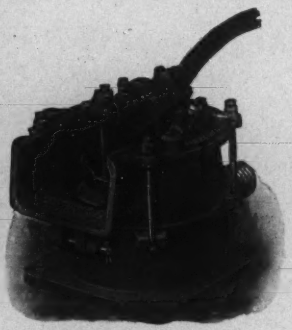
WALLACE & TIERNAN CO., Inc.

MANUFACTURERS OF CHLORINE AND AMMONIA CONTROL APPARATUS

NEWARK 1, NEW JERSEY • REPRESENTED IN PRINCIPAL CITIES

EDSON

PUMPS and ACCESSORIES



Hand Pumps – Power Pumps
Truck or Trailer Mounted
Edson Special Suction Hose
Red Seal Diaphragms
Edson Bronze Hydrant Pump
Strainers, Adapters, etc.

Distributors for
Pollard Pipe Line Equipment
Electric Pipe Thawers

Universal Pipe Locator
Universal Water Leak Detector

THE EDSON CORPORATION

49 D Street, Tel. SOUth Boston 3041 South Boston
New York: 142 Ashland Place, Brooklyn

Warren Foundry & Pipe Corp.

ALSO

Warren Pipe Co. of Mass., Inc.

SALES OFFICES
11 BROADWAY, NEW YORK
75 FEDERAL STREET, BOSTON, MASS.

Manufacturers of

CAST IRON PIPE

Flanged Pipe *Flexible Joint Pipe*
Bell and Spigot Pipe
Special Castings *Short Body B. & S. Specials*
Warren (WF) Spun Centrifugally Cast Iron Pipe

WORKS: PHILLIPSBURG, N. J. and EVERETT, MASS.

Large Stock Enables Us to Make Prompt Shipments

For an Extremely Smooth Pipe Interior

SPECIFY

SPUN **BITUMASTIC** LINING

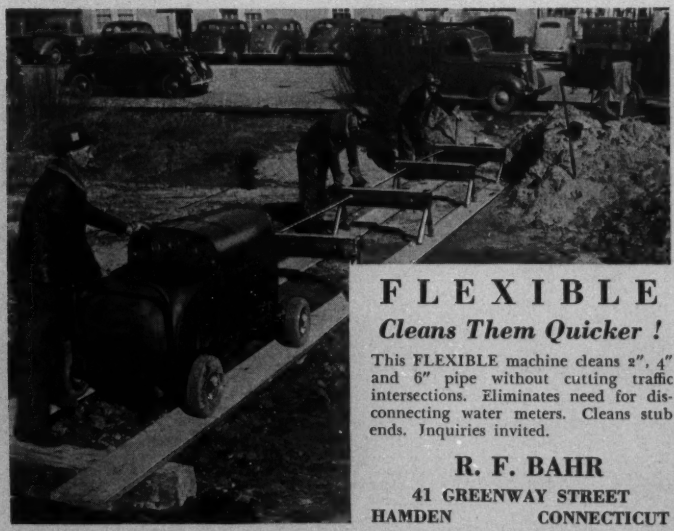
This Will Assure You of

NO LOSS IN CAPACITY
NO TUBERCULATION OR INCRUSTATION
NO EFFECT ON WATER QUALITY

Recent Repeat Flow Test Shows High Williams Hazen Coefficient Unchanged After EIGHT YEARS

Wailes Dove-Hermiston Corporation

General Offices: Westfield, N. J.
New York District Office: 17 Battery Place, N. Y. C.



FLEXIBLE

Cleans Them Quicker !

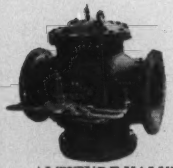
This FLEXIBLE machine cleans 2", 4" and 6" pipe without cutting traffic intersections. Eliminates need for disconnecting water meters. Cleans stub ends. Inquiries invited.

R. F. BAHR

41 GREENWAY STREET
HAMDEN CONNECTICUT

1879—ROSS— 1879

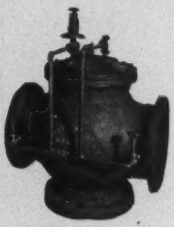
AUTOMATIC VALVES



Controls elevation of water in tanks, basins and reservoirs

ALTITUDE VALVE

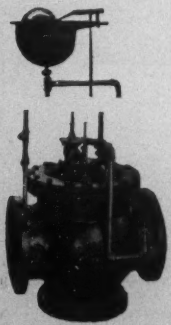
1. Single Acting
2. Double Acting



Maintains desired discharge pressure regardless of change in rate of flow

REDUCING VALVE

Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



Maintains levels in tank, reservoir or basin

1. As direct acting

2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

FLOAT VALVE

A self contained unit, with three or more automatic controls

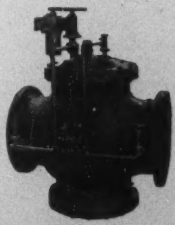
COMBINATION VALVE

Combination automatic control both directions through the valve.

Maintains safe operating pressures for conduits, distribution and pump discharge

SURGE-RELIEF VALVE

Electric remote control—solenoid or motor can be furnished



REMOTE CONTROL VALVE

Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

ROSS VALVE MFG. CO., INC. Box 592 TROY, N. Y.

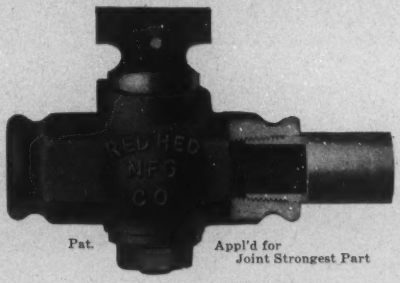


Fig. 220

RED HED Recessed Ends Curb Stops
With or Without Stop or Waste

WE ARE USING EVERY EFFORT

TO FURNISH

RED HED BRASS GOODS

FOR MAINTENANCE AND REPAIR REQUIREMENTS

RED HED MFG. CO.

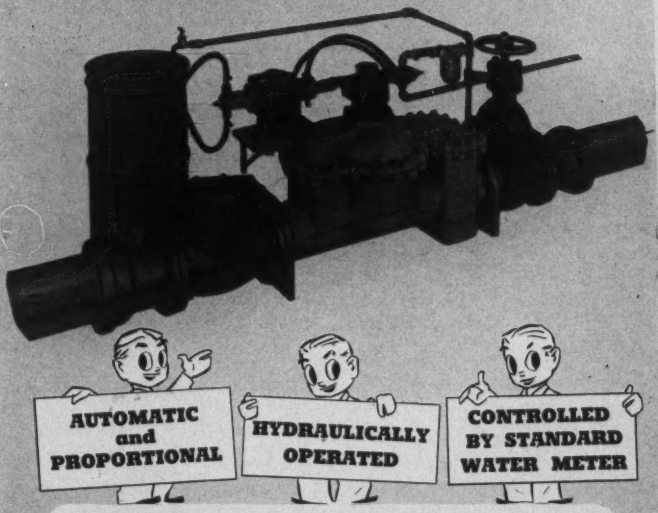
Manufacturers of

RED HED Brass Goods for Water Works

368 Congress Street Boston, Mass.

HIGH PRESSURE

Chem-O-Feeder



AUTOMATIC and PROPORTIONAL

HYDRAULICALLY OPERATED

CONTROLLED BY STANDARD WATER METER

DESCRIPTION: Hydraulically operated utilizing water power from main to inject against line pressures up to 175 lbs. per square inch, feeds in strict proportion to variable flow through mechanical disc, turbine, propeller or other type meters using only 5 times amount reagent fed daily for operating purposes. Meter accuracy not affected. Only two connections to main, no balancing water pressure required for operation of this plunger pump. Later installations of additional feeders for other chemicals using same control meter easily handled. Chem-O-Feeders may be located out of meter pit at convenient working level with remote control piping.

USES: In addition to chlorination of variable flow water systems, Automatic & Proportional High Pressure Chem-O-Feeder is used to feed:

ACTIVATED ALUM	LIME SLURRY
ALUM	SODIUM ALUMINATE
BLACK ALUM	CAUSTIC
SODA ASH	FERRIC CHLORIDE
FERROUS SULPHATE	SULPHURIC ACID
FERRIC SULPHATE	AQUA AMMONIA
CALGON	ALUMINUM SULPHATE, ETC.

PROPORTIONEERS, INC.

"Chemical Feeder Headquarters"

WRITE TO 63 CODDING ST., PROVIDENCE, RHODE ISLAND

What is all this talk about

POST WAR PLANNING

and why is it so necessary?

☆ ☆ ☆ ☆ ☆

At first glance people are apt to question the *PATRIOTISM* behind the idea of making plans *NOW* for work to be carried out after the war. They feel all efforts should be directed toward *FIRST* winning the war.

☆ ☆ ☆ ☆ ☆

Well, there certainly should be NO slackening of effort in that direction but it is also very necessary to "win the peace" on the HOME FRONT.

☆ ☆ ☆ ☆ ☆

Our boys on the battle fronts *MUST* be assured of two things when they return: *JOBS* and the best possible *LIVING CONDITIONS.*

☆ ☆ ☆ ☆ ☆

Jobs MUST be created to cushion the shock of conversion from a state of war to a peace time economy.

☆ ☆ ☆ ☆ ☆

And surely *nothing* is more important to general living conditions than "an adequate, safe and satisfactory water supply."

☆ ☆ ☆ ☆ ☆

At the same time we can guard against a return to the days of "boon-doggling" government financed, projects. YOU can control your own projects; do WHAT you need to, WHEN you need to, and with the MATERIALS you think BEST.

☆ ☆ ☆ ☆ ☆

This, then, represents the *HIGHEST* form of patriotism. It is more than a *PRIVILEGE,* it is a *DUTY* we owe to our country and our community.

☆ ☆ ☆ ☆ ☆

So let's start now on DEFINITE plans. It's not too EARLY; it may be LATE!

☆ ☆ ☆ ☆ ☆

Let's prove American *INITIATIVE* is still on the job! Let's get those projects designed! Let's arrange the financing! Let's *BLUE PRINT NOW!*

☆ ☆ ☆ ☆ ☆

Rensselaer Valve Company

TROY, NEW YORK

GUNITE

USED FOR RESTORATION OF DISINTEGRATED CONCRETE

RELINING RESERVOIRS - TANKS
PENSTOCKS

PRESSURE CONCRETE COMPANY

NO. 6 AVE. B NEWARK, N. J.

Pipe Founders Sales Corporation

CAST IRON PIPE AND FITTINGS

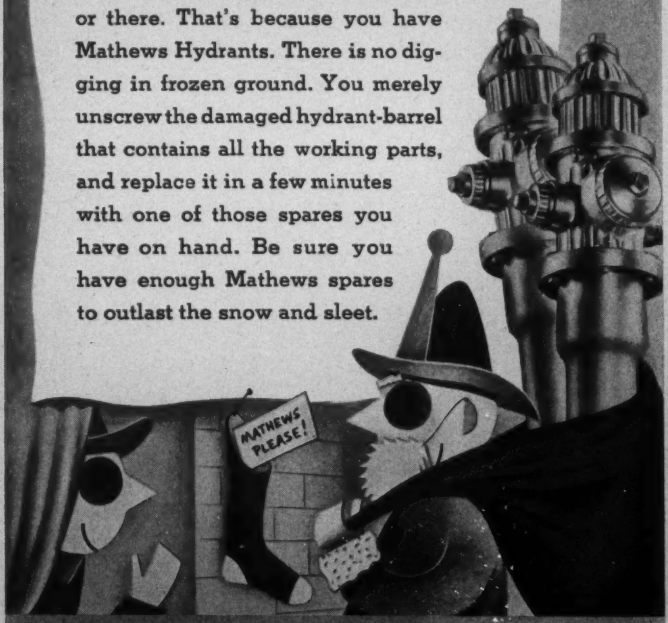
FOR

Water, Steam, Gas and Culverts
Special Flanged and Bell and Spigot Castings
Lyncast Iron Chemical Castings

Office: 6 Beacon Street, Boston Warehouse and Yard: East Cambridge, Mass.

WINTER TIME IS "STOCKING" TIME

Give yourself the peace-of-mind that comes with having plenty of spares on hand. Settle down to the long, cold winter amply protected against hydrant hazards. You won't have to worry too much if skidding cars and trucks *do* knock-off a hydrant here or there. That's because you have Mathews Hydrants. There is no digging in frozen ground. You merely unscrew the damaged hydrant-barrel that contains all the working parts, and replace it in a few minutes with one of those spares you have on hand. Be sure you have enough Mathews spares to outlast the snow and sleet.



MATHEWS HYDRANTS

400 CHESTNUT STREET, PHILADELPHIA, PA.

ESTABLISHED IN 1808

Made by R.D. WOOD Company

MANUFACTURERS OF SAND SPUN PIPE (CENTRIFUGALLY CAST IN SAND MOLDS) AND R. D. WOOD GATE VALVES

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BLUEPRINT NOW...

your postwar PLANS!

"Blueprint Now" is the official slogan of the national *Committee on Water and Sewage Work Development* organized and functioning, state by state, to get postwar plans out of the "talking" stage into blueprint form—detailed plans and specifications—so that construction can start at the drop of a hat, when armistice comes.

The Cast Iron Pipe Research Association gladly contributes additional publicity to the furtherance of this program. It is of prime importance to the community and the nation.

Water supply, gas and sewerage systems have been starving for needed improvements, and getting along on a bare subsistence diet for maintenance, in order to conserve manpower and materials for the war effort.

When war priorities are lifted, every community expects, and is entitled, to have these vital public services restored to full efficiency *without delay*. When returning service men are looking for work, the nation will expect that the vast reservoir of millions of man-hours of employment, represented by this deferred construction, will be ready to be tapped—*without delay*.

The way to prevent delay is to *blueprint now*. Remember that when the "dam" breaks on deferred projects—general building construction as well as underground mains—there may be a temporary shortage of certain materials until plant conversions are effected. However, cast iron pipe will be available, then as now, *without delay*.

CAST IRON PIPE

For Delivery Now

Stacked on the storage yards of our several plants are ample stocks of cast iron pipe in sizes most commonly used, ready for immediate delivery. Standard fittings are also quickly available. Where requirements cannot be supplied from stock on hand, we are in position to produce them promptly. In connection with postwar plans you can rely on securing Super-de Lavaud or U. S. pit-cast pipe *when you need it*, as our facilities for pipe production have not been reduced in spite of our past and present contribution to the war effort.

Pipe storage and shipping yard at one of our plants, drawn by Hugh Ferris.

UNITED STATES PIPE & FOUNDRY CO.

General Offices: Burlington, N. J. ***Plants and Sales Offices Throughout the U. S. A.***

The Journal of the New England Water Works Association

is a quarterly publication, containing the papers read at the meetings, together with reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness.

All members of the Association receive the JOURNAL for two dollars per annum which sum is included in their annual dues; to all others the subscription is four dollars per annum.

TO ADVERTISERS

THE attention of parties dealing in goods used by Water Departments is called to the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION as an advertising medium.

Its subscribers include the principal WATER WORKS ENGINEERS AND CONTRACTORS in the United States. The paid circulation is **1000** COPIES.

Being filled with original matter of the greatest interest to Water Works officials it is PRESERVED and constantly REFERRED TO BY THEM, and advertisers are thus more certain to REACH BUYERS than by any other means.

The JOURNAL is not published as a means of revenue, advertisements being inserted solely to help meet the large expense of publication.

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One-half page, single insertion	Thirty Dollars
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Size of page 4½ x 7½ net.

A sample copy will be sent on application.

For further information, address the Advertising Agent,

MISS MILDRED LIGHTBODY,
613 STATLER BUILDING,
BOSTON, MASSACHUSETTS

LEADITE

COSTS ARE REDUCED WHEN *LEADITE* IS USED

Of course, the greatest advantage in using LEADITE, is, that it makes a good, tight joint,—and thus reduces leakage to a minimum,—but LEADITE also offers the following advantages, which are worthy of serious consideration: Saves caulking expenses—Reduces cost of digging large bell-holes —Saves in cost of material—Reduces time required for pumping "wet trenches"—Saves time in preparation—Saves time in handling on the job—Saves in freight and hauling charges.

Another point, LEADITE saves "interest charges" by speeding up the completion of the water line.

The true value of LEADITE is best indicated by the fact that it has been used on THOUSANDS OF MILES of Water Mains,—all over this Country, as well as in many Overseas Countries.

The Pioneer self-caulking material for c. i. pipe,
Tested and used for over 40 years,
Saves at least 75%.

THE LEADITE COMPANY

Girard Trust Company Building — Philadelphia, Penna.

No Caulking